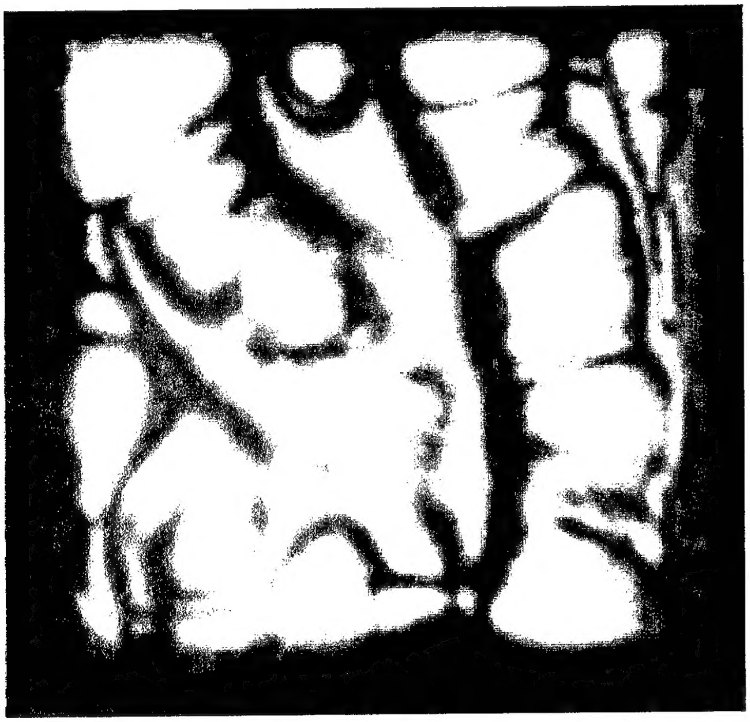

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St.Petersburg, Russia July 5-9, 1999

Book of Abstracts

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7th INTERNATIONAL WORKSHOP ON THE PHYSICS OF COMPRESSIBLE TURBULENT MIXING

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July 5-9, 1999
St.Petersburg, Russia

ВНИИЭФ VNIIEF

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GENERAL INFORMATION

The 7th International Workshop on the Physics of Compressible Turbulent Mixing will be held in St.Petersburg from July 5 to 9, 1999, at the State Regional Educational Center (SEC) of the Ministry of RF for Atomic Energy
Address SEC: 197348, St.Petersburg, Aerodromnaya street, 4, RUSSIA
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Information about SEC you can get from Web site: http::/www.graph.runnet.ru

The opening session will start at 8.45 on Monday, July 5. The other sessions will start at 9.00. The conference will conclude at 18.00 on Thursday, July 8.

The social program is scheduled for Friday, July 9.

The registration desk will be open from Sunday, July 4 16.00 and from Monday, July 5 8.00.

The general program is as follows:

1st day, July 5th: Three oral sessions will take place, followed by a poster session at the conclusion of the first conference day. A reception will close the first day.
2nd day, July 6th : Three oral sessions will take place on this day. A Round-table discussion, topic «Experimental», will conclude the second day of conference.
3rd day, July 7th : Three oral sessions will take place on this day. A Round-table discussion, topic «Numerical», including test calculation results will conclude the work day of conference. A Banquet will close the third day.
4th day, July 8th : Three oral sessions will take place on this day. A Round-table discussion, topic «Theoretical», will be held and final conclusions of the conference made at the close of the fourth day.
5th day, July 9th : Cultural Program – Workshop participants excursion to "Tsarskoye Selo".

The working language for the Workshop is English.

FINANCIAL SUPPORT ORGANIZATIONS

Aldermaston Weapon Establishment, UK
Commissariat a l'Energie Atomique/ Direction des Application Militaires, FRANCE
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European Research Community On Flow Turbulence And Combustion (ERCOFTAC)
Lawrence Livermore National Laboratory, USA
Ministry for Atomic Energy, RUSSIA
Russian Fund of Fundamental Investigations, RUSSIA
Universte de Provence, FRANCE

CONTENTS

Abstract number: 101

Simulations of Gelatin-Ring Experiments

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Abstract: We present two-dimensional direct numerical simulations of gelatin-ring experiments carried out by Weir et al. (Phys. Rev. Letters 80, 3763 (1998)). We use the Arbitary Lagrangian-Eulerian hydrocode CALE for our simulations which track the implosion as well as the bounce of the gelatin rings with a variety of surface perturbations. An analytic theory of the Rayleigh-Taylor and Richtmyer-Meshkov instability in cylindrical geometry, valid only in the linear regime, will also be presented.

Abstract number:102

The Instability Growth and Transition to Turbulence of a Shock-Accelerated Gas Curtain

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Abstract: Our investigation of Richtmyer-Meshkov (RM) instability in a gas curtain formed by two adjacent density interfaces has produced a quantitative characterization of the onset of disordered features in a vortex-dominated flow, and the subsequent transition to turbulence. Early studies examined integral measures of the instability growth [1-4]. Recent work investigated transitional flow [5-7] and integral comparisons to simulations [8].

These experimental results have been used effectively for validating computational simulations of highly-distorted flows [9]. These studies clearly demonstrate the usefulness of gas-curtain experiments to study transition to turbulence.

In our experiment, a curtain of heavy gas (SF_6) is injected vertically through a shaped varicose nozzle into the test section of a horizontal shock tube filled with lighter gas (air). The flow in the curtain is laminar and slow (10 cm/s). The curtain formed by the SF_6 is initially varicose in cross section, and because the curtain is formed without using membranes to separate the air and SF_6, the interfaces are diffuse. Some experiments have single-wavelength perturbations while others are multi-mode. The curtain is impulsively accelerated by a Mach 1.2 normal shock, which deposits baroclinically-generated vorticity on the interfaces. This acceleration and vorticity production causes RM instability of both nearby interfaces and this leads to vortex roll-up, nonlinear perturbation growth in the curtain and eventually to turbulence. The effect of reshock on the turbulent transition will also be examined.

To quantify the gas-curtain evolution, we use high-speed optical diagnostics based on laser-sheet illumination. We have been using multi-frame imaging and we are now adding Particle Image Velocimetry (PIV) to map velocity and vorticity fields. The curtain material (SF_6) is premixed with a small volume fraction of a passive tracer in the form of glycol droplets (with a characteristic diameter of less than one micron). A powerful multiple-pulse laser illuminates a light sheet within the flow, producing a series of images recorded with high-resolution, intensified or cooled CCD cameras. The high temporal resolution is achieved by using a series of short-duration laser pulses (10 nanoseconds). The pulses may be programmed at relatively large intervals to produce a multi-frame imaging sequence or they may be programmed in pulse-pairs with small intervals for velocimetry. Autocorrelation of the image with the pulse pair resolves tracer particle displacements in the image series and thus recovers the velocity field.

The primary objective of the experiment is to study the spatial evolution of the RM instability by producing quantitative measurements of the vorticity deposited by the shock interaction and to use these measurements to determine the influence of large- and small-scale structures on the flow evolution. We present instantaneous sectional velocity and vorticity fields in the plane of the light sheet and compare these results with other quantitative diagnostics based on images of these fields. The results show details of the onset of disordered flow that leads to turbulence.

This study is supported by US Department of Energy contract number W-7405-ENG-36.

References

1. J.W.Jacobs, D.L.Klein, D.G.Jenkins, and R.F.Benjamin, "Instability growth patterns of a shock-accelerated thin fluid layer,"Physical Review Letters 70, 583 (1993).
2. J.M.Budzinski, R.F.Benjamin, and J.W.Jacobs, "Influence of initial conditions on the flow patterns of a shock-accelerated thin fluid layer, "Physics of Fluids 6, 3510 (1994).
3. J.W.Jacobs, D.G.Jenkins, D.L.Klein, and R.F.Benjamin, "Nonlinear growth of the shock-accelerated instability of a thin fluid layer," Journal of Fluid Mechanics 295, 23 (1995).
4. P.M.Rightley, P.Vorobieff and R.F.Benjamin, "Evolution of a Shock-Accelerated Thin Fluid Layer," Physics of Fluids 9, 1770 (1997).
5. P.Vorobieff, P.M.Rightley and R.F.Benjamin, "Power-law spectra of incipient gas-curtain turbulence," Physical Review Letters 81, 2240 (1998).
6. P.M.Rightley, P.Vorobieff, and R.F.Benjamin, "Experimental observations of the mixing transition in a shock-accelerated gas curtain," to be published in Physics of Fluids (1999).
7. P.Vorobieff, P.M.Rightley and R.F.Benjamin, "Shock-driven gas curtain: fractal dimension evolution in transition to turbulence,"submitted to Physica D (1999).
8. R.M.Baltrusaitis, M.L.Gittings, R.P.Weaver, R.F.Benjamin and J.M.Budzinski, "Simulation of shock-generated instabilities," Physics of Fluids 8, 2471 (1996).
9. J.Kamm, W.Rider, P.Vorobieff, P.M.Rightley, K.Prestridge and R.F.Benjamin, "Analysis and Comparison of Experimental and Simulated Compressible Mixing,"submitted to International Workshop on the Physics of Compressible Turbulent Mixing (1999).

Abstract number: 103

Analysis and Comparison of Experimental and Simulated Compressible Mixing

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Abstract: He qualitative and quantitative relationship of numerical simulations of compressible mixing to the physical phenomena being modeled is of preeminent importance in establishing the validity of these calculations. Since these phenomena are dominated by irregular (i.e., non-smooth, non-deterministic) behavior, there is no clear path by which to establish this correspondence. In this work, we attempt to unify the examination of the details of specific experimental results and the validation of the corresponding numerical simulations.
Our principal experimental basis is provided by the gas curtain Richtmyer-Meshkov experiment of Rightley et al. [1] This experiment involves shock accelerating a curtain of SF_6 gas with a Mach 1.2 shock wave and examining the subsequent fluid mixing driven by the deposition of baroclinic vorticity in the gas curtain. We simulate the experiment with the adaptive mesh code RAGE [2] and the research code Cuervo [3]. Both codes use Godunov-type methods, although they differ significantly in the other algorithmic details. We also consider extensions of this work to the incompressible Rayleigh-Taylor instability as exhibited by the linear electric motor (LEM) experiment of Dimonte et al. [4], for which the corresponding calculations are performed with an incompressible flow code.
We consider three analysis techniques: (1) structure functions, (2) fractal analysis, and (3) continuous wavelet transforms. Our primary focus is on the first two of these methods, with which we seek some evidence of power law behavior at length scales associated with the mixing layer. These power laws evolve temporally and may reveal the signature of transitional phenomena occurring in the layer.
The experimentally obtained Richtmyer-Meshkov instability data exhibit scale similarity in a reproducible fashion for both structure functions [5] and fractal dimension [6]. These results demonstrate the utility of these techniques as sensitive diagnostics of transitional flow. Corresponding 2D numerical simulations also demonstrate power laws; however, some simulation results correspond to those of experiments, while others deviate significantly. It appears that the details of the numerical integration provide a mechanism for this variation. The differences in the analyzed results of the simulations may lead to criteria that guide the selection of the numerical method(s) appropriate for specific physical phenomena. Quantitative correspondence between the analyzed results of experiment and computation would provide a validation exercise that leads to confidence in the numerics.
There remain deeper questions regarding the capacity of numerical methods to appropriately simulate phenomena in the inertial scale-similar range while not fully resolving the dissipation range. Furthermore, we seek some ability to quantitatively distinguish between 2D and 3D effects, and to discriminate between intrinsically incompressible and fundamentally compressible phenomena. Such capabilities are essential in situations where no conceivable increase in computer power would remedy this problem. Our intention is to provide measures of the ability of numerical methods to simulate physical behavior at scales between an integral range and the grid scale, where some sort of dissipative cutoff must be enforced.

1. Rightley, P.M., Vorobieff, P., and Benjamin, R.F., Evolution of a Shock-Accelerated Thin Fluid Layer, *Phys. Fluids*, **9** (6) pp. 1770-1782 (1997), and earlier references cited therein.
2. Baltrusaitis, R.M., Gittings, M.L., Weaver, R.P., Bemjamin, R.F., and Budzinski, J.M., Simulation of Shock-Generated Instabilities, *Phys. Fluids*, **8** (9) pp. 2471-2483 (1996).
3. Rider, W.J., An Adaptive Riemann Solver Using a Two-Shock Approximation, Los Alamos National Laboratory Report LA-UR-97-1796 (1997), to be published in *Computers and Fluids*.
4. Schneider, M.B., Dimonte, G., and Remington, B., Large and Small Scale Structure in Rayleigh-Taylor Mixing, *Phys. Rev. Lett.*, **80** (16) pp. 3507-3510 (1998).
5. Vorobieff, P., Rightley, P.M., and Benjamin, R.F., Power-Law Spectra of Incipient Gas-Curtain Turbulence, *Phys. Rev. Lett.*, **81** (11) pp.2240-2243 (1998).
6. Vorobieff, P., Rightley, P.M., and Benjamin, R.F., Shock-driven Gas Curtain: Fractal Dimension Evolution in Transition to Turbulence, submitted to *Physica D*.

Abstract number: 104

Multimaterial Flow Models for ICF Mixing

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Abstract: This report will discuss two topics concerning mixing of condensed matter in physical regimes that occur in ICF.

The first topic to be discussed is a multiphase flow model with nonequilibrated temperatures but with equal velocities and pressures for each species. Turbulent mixing is driven by diffusion in these equations. The closure relations are defined in part by reference to a more exact chunk mix model previously derived by the authors and coworkers that has distinct pressures, temperatures, and velocities for each species. We will discuss a multi-temperature, multi-species thermodynamics with equilibrated pressures for use in this application, as well as the determination of coefficients occuring in the diffusion closure relations and the form of the Reynolds stress tensor.

The second part of the report will present recent results on the Rayleigh-Taylor and Kelvin-Helmholtz instability in metals. The results of a linear analysis of the small amplitude regime as well as numerical results for the nonlinear regime will be described.

Abstract number: 105

Subgrid Models and DNS Studies of Fluid Mixing

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Abstract: This is a group report on results by the author and collaborators. We study single and multimode acceleration driven interface instabilities and mixing layers. These direct simulation results provide input to and validation for subgrid models of turbulent mixing.
For the late time evolution of a single Rayleigh-Taylor (RT) mode, we show that the approach to terminal velocity is nonuniform. The bubble and especially the spike velocity is non-monotone and possibly oscillatory. Late time Richtmyer-Meshkov modes show some departure from a previously proposed analytic model of Zhang and Sohn. They also show departure from self-similarity of mixing, as is expected from asymptotic expressions for the growth of the mixing zone edges.
In three dimensions, we investigate secondary instabilities of oblong bubbles, leading to tip splitting. We show preliminary results on the breakup of a turbulent jet. Random interface results will be presented.
A new and simplified multiphase flow model obtained by averaging the macrophysical equations will be presented. It supports distinct temperatures for each phase but has a single fluid pressure and velocity.

Abstract number: 106

Membrane Effects on the Richtmyer-Meshkov Instability

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Abstract: Membranes have been used extensively in past shock-tube investigations of the Richtmyer-Meshkov instability, to separate the gases forming an interface. These have included custom-made nitrocellulose or commercially available Mylar films (on the order of 1 micron thickness). Many of the past studies have investigated the effects of the membranes and their rupture upon shock interaction on the Richtmyer-Meshkov instability. In general, it is believed that the membrane or its fragments may affect the growth of the instability and the mixing zone. It has also been proposed that the membranes will get pyrolized due to shock heating for strong shocks.

Here we present results from a detailed study investigating the effects of both mylar and nitrocellulose membranes. A large range of Mach numbers ($2<M<5$) into atmospheric pressure gas is covered to study the effect of the strength of the incident shock-wave on the membrane rupture. These high Mach numbers are achieved by a new high pressure (20 MPa) shock-tube with an inner cross section of 24.5 x 24.5 cm. Thin wires are used to support the membrane and also facilitate its rupture into smaller fragments which may have less effect on the growth rate. It is shown that if wires are not used on the frame supporting the membrane the membrane is torn off at the edges and remains intact as it travels downstream. A number of 'air-air' shots have been performed to observe this fact. With the wires in place, the membrane is broken into small fragments which flow downstream with the mean motion of the interface. The membrane is not destroyed for weak shocks and remains intact, this may affect the growth rate of the instability due to changes in the flow induced by the membrane. It may also pose significant problems in optically measuring the thickness of the actual interface and the instability growth rate. If the membrane remains intact it may obscure the interface and lead to inaccurate measurements of the growth of the interface.

Although there are problems with using membranes to create discontinuous interfaces, they still remain the only way to create a true discontinuous layer of two gases. The objective of this study is to qualify the effect of the membrane and discuss what conditions are necessary to obtain a worthwhile information from Richtmyer-Meshkov instability growth rate studies using thin membranes.

Abstract number: 107

Experimental Investigation of the R-M Instability for Strong Incident Shocks

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Abstract: The instability of any perturbations on a density interface accelerated by a shock-wave (the Richtmyer-Meshkov Instability) is one of the important obstacles that needs to be overcome in order to achieve useful energy yield in the implosion of the inertial confinement fusion (ICF) targets filled with deuterium-tritium (D-T) fuel. The instability amplifies the perturbations present at the ablator-fuel interface and dilutes the fuel consequent to the mixing between the ablator material and the fuel, lowering the yield. Shock-tube experiments have been performed in the past to study the growth of the instability on a shock-accelerated interface. However, the structural capability of the existing shock-tubes limited the investigations to weak shocks, characterized by $M \leq 2.0$, released into gases at atmospheric pressure. In order to produce stronger shocks and still not exceed the structural capability of the shock-tubes, the driven gases were often kept at subatmospheric pressure.

But this resulted in large wall vortices, produced as a result of the interaction between the shock reflected of the end of the shock-tube and the thick boundary layer that forms behind the incident shock because of the low kinematic viscosity. These vortices have been believed to exert a strain on the interface, precluding an accurate quantification of the growth rates of the perturbations present on the shocked interface. The effects of vorticity have been shown to be proportionally more important in shock-tubes of small cross-sections.

We present the first experiments performed to overcome these limitations. A new shock-tube facility has been designed specifically for this study. The shock-tube is vertical, with a 25 x 25 cm square cross-section, with a maximum load capacity of 20 MPa. Two types of interfaces can be studied: the continuous ones prepared by retracting a thin metal plate initially separating the two gases forming the interface prior to firing the shock and the discontinuous ones prepared using a thin nitrocellulose or mylar membrane. The membrane can be formed into a sinusoidal shape using a suitably contoured holding frame, so that desired initial conditions can be imposed. The incident shock Mach numbers are in the 2-4 range, with the driven and test gases initially at atmospheric pressure. Both schlieren and planar (Rayleigh Scattering) imaging of the interface are performed and the time evolutions of the amplitude of the perturbations and the thickness of the mixing zone are reported in this strongly shocked regime.

Abstract number:108

NOVA Experiments Examining Rayleigh-Taylor Instability in Materials with Strength

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Abstract: Material strength can affect the growth of the Rayleigh-Taylor instability in solid materials [1,2], where growth occurs through plastic flow. In order to study this effect at megabar pressures, we have shocked metal foils using hohlraum x-ray drive on Nova, and observed the growth of pre-imposed modulations with x-ray radiography. Previous experiments employing Cu foils [3] did not conclusively show strength effects for resolvable wavelengths. Therefore, we have redesigned the experiment to use aluminum foils. As aluminum has higher specific strength at pressures ~1 Mbar, the new design is predicted to show growth reduction due to strength of at least a factor of two for some wavelengths in the observable range of 10–50 cm. We have also modified the drive history to extend the interval of uniform acceleration and to reduce the risk of melting the foils with coalesced shocks. The design changes, as well as Nova operational constraints, limit peak pressures to 1-1.5 Mbar. However, our goal is to reach multimegabar pressures with this technique, either through direct drive on Omega or with more energy on NIF. We have placed more emphasis in the new experiments on diagnosing the sample state, to verify that melt has not occurred. Foil surface motion has been measured with high sensitivity by laser interferometry to look for thermal expansion. We have continued to pursue dynamic x-ray diffraction as the most definitive measurement of crystal state. We shall discuss design of the modified experiment, and present comparison of data with simulations for interferometric and diffraction experiments as well as for Rayleigh-Taylor experiments.

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

References

1. J.F. Barnes *et al.*, J. Appl. Phys. **45**, 727 (1974).
2. A.I. Lebedev, *et al.*, in *The Physics of Compressible Turbulent Mixing*, G. Jourdan and L. Houas eds., p. 307, (1997).
3. D.H. Kalantar *et al.*, in *The Physics of Compressible Turbulent Mixing*, G. Jourdan and L. Houas eds., p. 232, (1997).

Abstract number: 109

Buoyancy-Drag Model for Rayleigh-Taylor Mixing and Comparison with Experiments

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Abstract: A new buoyancy-drag model for Rayleigh-Taylor (RT) mixing is constructed on the premise that the bubble and spike regions behave as distinct and homogeneously mixed fluids with densities between those of the original fluids. The average intermediate densities are calculated assuming a piece-wise linear density profile in the mixing zone. They are then used to calculate the inertia and buoyancy terms in the equation of motion explicitly, leaving the Newtonian drag coefficient C as the only unknown. The model is able to describe RT experiments over a comprehensive range of acceleration histories $g(t)$ and Atwood numbers A. The bubble (i = 1) and spike (i = 2) amplitudes are found to increase as $h_i = \theta_i A g t^2$ for a constant g and as a power law $h_i \sim t^{\theta_i}$ for an impulsive g. For the bubbles, both α_1 and θ_1 decreases slightly with A. For the spikes, both α_2 and θ_2 first increase slowly with A and then rise sharply above A = 0.8 toward the free fall values. However, the model predicts that the exponents are not universal, but depend on the initial conditions, as is observed in numerical simulations. This new model is also compared with laser driven experiments and previous two-phase flow models.

Abstract number: 110

Material Failure and Instability Growth Experiments in Solid Aluminum on the Pegasus II Z-Pinch

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Abstract: Experiments involving convergent shock waves applied to Al cylinders have been performed on the Pegasus II z-pinch facility at Los Alamos National Laboratory. Two Al alloys with differing yield strengths have been studied at shock pressures of from 14 to 50 GPa. Material failure in the form of broad bands of microspalled material has been observed. In additon, sinusoidal patterns inscribed on the inner Al surface have produced pattern growth in the microspalled material as well as perturbations on the surface. Experiments show variations in pattern formation as a function of wavelength, normalized perturbation amplitude, and shock pressure.

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Abstract number:111

Unstable Interfaces Driven by Strong Shocks in Cylindrical Geometry

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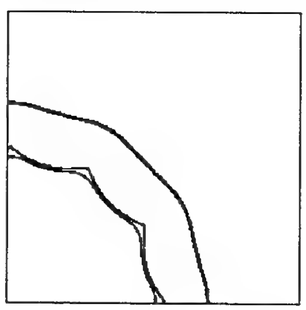
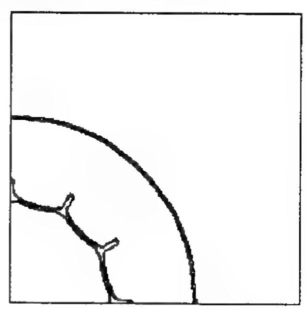
Abstract: The study of Richtmyer-Meshkov (RM) Instabilities has attracted many researchers in recent years, due to the fact that this instability plays an important role in inertial confinement fusion and supernovas. Experimental studies of the RM unstable interface driven by strong shocks (Mach number > 20 have been achieved). Most of the numerical studies of the RM unstable system have been and are being performed in planar geometry and for incident shocks with small or intermediate Mach number. We consider the RM unstable interface driven by strong shocks in cylindrical geometry and establish an important scaling law. This scaling law will allow researchers to significantly reduce the number of experiments and numerical simulations required in the study of RM unstable interfaces driven by strong shocks.

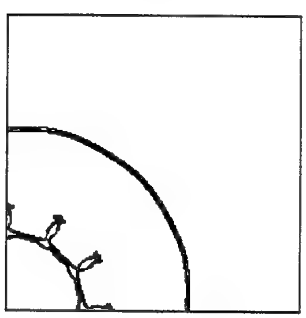
Evolution of the Interface for Air-SF_6,
Mach Numbers 10, 15, 40 and 100 Superimposed.



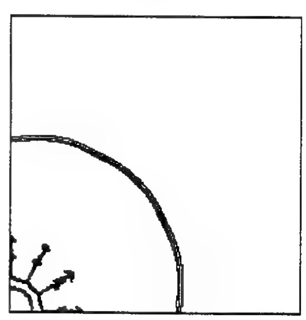
(a) t=0.57



(b) t=0.83



(c) t=1.0



(d) t=1.3

Abstract number:112

Application of a k-l Turbulent Mix Model to Double Shell Implosions

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Abstract: We used a *k*-l turbulent mix model, integrated in a hydro code, to model a series of double shell implosions. The double shell implosions were laser-driven experiments performed at the NOVA laser. The double shell implosions illuminate the turbulent mixing process in a convergent, compressible hydrodynamic regime. We briefly review the turbulent mix model. The model has four adjustable parameters: amplitudes for the growth and dissipation terms; an initial length scale; and an initial wavelength scale. These are set by comparison to classical experiments. Next we briefly describe the experiment. The target assembly consists of an inner shell of glass and an outer shell of brominated plastic. The glass shell is filled with deuterium gas. The target is placed in a cylindrical hohlraum. We present the analysis of the hydrodynamic implosion, using the turbulent mix model. The dependence of mixing rate on model parameterization is described.

Abstract number: 113

Statistical Characterization of the Rayleigh-Taylor Mixing Layer Using a Two-Field Flow Decomposition

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Abstract: Many mathematical models of turbulent Rayleigh-Taylor mixing layers rely on statistical descriptions of the mixing layer dynamics. For example, models of the «k-ε» and «R_{ij}-ε» class rely on averages of moments of the Navier-Stokes equations to construct the equation for the second moment of the velocity fluctuation, the so-called Reynolds stress, R_{ij} or its trace, $R_{nn}=2k$. Due to the nonlinearity of the Navier-Stokes equations, the evolution equation for the «n-moment» will contain the «$(n+1)$st –moment», etc. A variety of assumptions may be invoked, either explicitly or implicitly, to «close» the resulting infinite hierarchy of moment equations. An alternate mathematical description of the mixing layer as proposed by Cranfill [1] and by Youngs [2] among others, is to construct a multi-field flow description of the mixing layer. The ideas associated with the «k-ε» and «R_{ij}-ε» class of turbulence models are then used to model the interactions of the flow fields. Again, these descriptions rely on the statistics of the flow fields to construct both the multi-field equations as well as the turbulence dynamics that couple the fields. In this present work, we have performed a series of simulations of two- and three-dimensional mixing layers using the Lattice Boltzmann Method of He, Chen and Zhang [3] to produce a statistical ensemble with which to assess the two closure alternatives described above. Analysis of the statistics indicates that the multi-field description results in fluctuating quantities that are more nearly «gaussian» than those in the single-field descriptions, but that fluctuations are still significantly «non-gaussian».

References

1. C. W. Cranfill, «A New Multifluid Turbulent Mix Model,» Los Alamos National Laboratory Report LA-UR-92-2484, August, 1992.
2. D. L. Youngs, «Modelling turbulent mixing by Rayleigh-Taylor instability,» in Advances in Fluid Turbulence, Physica D, Vol. 37, 1989 pp. 270-287.
3. X. He, S. Chen, R. Zhang, «A Lattice Boltzmann Scheme for Incompressible Multiphase Flow and Its Application in Simulation of Rayleigh-Taylor Instability,» July 1998, Accepted by J. Comp.Phys.

Abstract number: 114

A K-L Turbulent Mix Model for ICF Targets

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Abstract: A phenomenological turbulent mix model has been developed and applied to ICF targets. The model evolves two variables, K and L in space and time. The variable K represents the kinetic energy of the unthermalized and unresolved turbulence. L represents the longest characteristic wavelength of the turbulence. The adjustable parameters of the model are set by matching classical Rayleigh-Taylor and Richtmyer-Meshkov experiments. The governing equations of the model are presented and discussed along with comparisons to data from Rayleigh-Taylor and Richtmyer-Meshkov experiments as well as to laser driven experiments performed on NOVA.

Abstract number: 115

A Numerical Study of Turbulent and Multiphase Phenomena in Rayleigh-Taylor Mixing

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Abstract: Chaotic fluid mixing exhibits a rich variety of both turbulent and interfacial effects. However, these two types of phenomena are rarely considered simultaneously in the context of subgrid modeling. In this talk, we present results of recent front-tracking simulations of Rayleigh-Taylor instability in two spatial dimensions. The initial configuration is a randomly perturbed planar interface separating two weakly compressible ideal gases. We use a very fine computational grid, where near pointwise convergence of the tracked contact surface (a sensitive parameter) is achieved. Our analysis concerns physical aspects of the mixing relevant to the closure of the phase-averaged Euler equations, such as the mixing layer growth rate, the Reynolds stress, velocity and pressure separation, and interfacial effects. We also explore the statistical convergence of mean flow quantities as the ensemble size increases. Finally, we discuss some of the major obstacles encountered in our effort to use simulations data to test modeling assumptions.

Abstract number: 116

Random Interface Richtmyer-Meshkov Instability in Planar and Cylindrical Geometry

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Abstract: The majority of experimental, theoretical and numerical investigations of Richtmyer-Meshkov instability (RMI) have assumed a planar, shock-tube geometry. However, most of the interesting applications of RMI are in convergent (ICF capsule implosion) or divergent (supernovae explosion) geometries. Convergent-geometry RMI differs from planar-geometry RMI in several ways, including the inevitable reshock of the interface and the addition of Rayleigh-Taylor effects arising from the radial pressure gradients.

In this work we study RMI-induced mixing of two ideal gases at a randomly perturbed interface in planar and cylindrical (imploding) geometry. Numerical results are obtained from two different Eulerian hydrodynamics codes, FronTier and RAGE. Our analysis concerns how geometry affects the growth and internal structure of the mixing layer, and how the simulation data can be applied to the development and validation of a class of growth rate and two-phase flow models. We also examine how the two simulation codes compare on identical problems.

Abstract number: 117

Spectral Measurements and Modeling of Density Fluctuations in Rayleigh-Taylor Mixing

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Abstract: A water channel experiment to study 3-D Rayleigh-Taylor mixing has been used to measure density fluctuations in a stochastically stationary mixing layer. Thermocouples measure temperature/density values over periods much longer than the largest time scale to obtain spectral distributions at discrete locations in the spatially-evolving mixing layer. Assertion of the ergodic hypothesis relates two-time series statistics to approximate two-point spatial statistics in a time-evolving mixing layer. Auto correlations of density fluctuations are Fourier transformed to give power spectral density (PSD) functions. Atwood numbers, 5.6e-4 and 1.1e-3, have been investigated, with a detailed study of a non-self-similar state, and late self-similar development of the scalar PSD. Ultimately, through the action of a diffusive cascade in spectral space, initial conditions are lost and a self-similar evolution proceeds. As a first attempt to validate modeling of cascade terms in a spectral transport model for turbulence, a 1-D code in wave number space demonstrated that the implementation of inverse and direct cascade is necessary to simulate the early evolution and transition to self-similarity of the scalar PSD. During the early evolution of the scalar PSD in the model, local maxima in the spectral distribution appear in the intermediate wave number range. Later in the evolution of the mixing layer the local maxima were dissipated, and the scalar PSD evolved self-similarly with a k-5/3 scaling. However, experiments showed that at intermediate wave numbers the scalar PSD evolved self-similarly with a k-5/3 power law, while at higher wave numbers the scalar PSD evolved self-similarly with a k-3 scaling.

Abstract number:118

Richtmyer-Meshkov Instability in Cylindrical Explosions

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Abstract: Recent experiments have been conducted at the Lawrence Livermore National Laboratory observing the behavior of an explosively shocked copper ring. These experiments, conducted by K. Budil of LLNL, were performed on the NOVA laser. In the experiments a direct laser drive using a square pulse was used to irradiate the center of a copper ring with specified perturbations engineered on the exterior of the ring. This lecture will discuss the numerical simulation and modeling of this set of experiments. Two different codes were used for the simulations, the adaptive mesh refinement radiation hydrodynamics code RAGE, developed at the Science Applications International Corporation and the Los Alamos National Laboratory, and FronTier, a hydrodynamic front tracking code developed at the University of Stony Brook and the Los Alamos National Laboratory. RAGE initiates the instability by specifying a time dependent temperature profile in the interior of the ring, which is an approximation to the energy deposited by the laser. This process generates an ablation shock at the interior of the ring that drives Richtmyer-Meshkov instability at the outer edge. FronTier uses the hydrodynamic initial conditions specified by RAGE at a time shortly after the production of the ablation shock but before this shock has reached the outer edge of the ring. The computations will compare the relative advantages of the sharp interface model used in FronTier with the adaptive mesh strategy used in RAGE. Since the laser pulse has a short duration with respect to the time scales that Richtmyer-Meshkov instability grows, it is expected that differences in the mathematical models used in the two codes are primarily limited to the early time initiation of the shock wave. The output from the two codes will seek to measure the influence of the expanding geometry on the perturbation growth rates. A companion set of computations will be performed using a rectangular geometry to compare and contrast the behavior of the unstable interfaces in the two cases.

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Abstract number:119

Rayleigh-Taylor Instability Initiated by Acoustic Waves

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Abstract: An acoustic wave traveling from a stable accelerated fluid into an unstable region triggers Rayleigh-Taylor growth in the unstable region. This is a nonlinear wave interaction, requiring a treatment via 2nd-order theory. We expect a situation something like this to arise in ICF capsules when perturbations travel as acoustic waves from the inside of the capsule outward to the ablation surface, a process called feedout. As a step towards a fundamental understanding of this process, we present numerical simulations of acoustic waves traveling up the density gradient (i.e., downward) in a stable hydrostatic atmosphere and entering an unstable layer of reversed density gradient, where they stimulate Rayleigh-Taylor instability. We also give results from a 2nd-order analysis of the wave interaction.

This work was supported by the US Department of Energy under contract W-7405-ENG-36.

Abstract number:120

Comparison of Richtmyer-Meshkov Instability Growth and Mixing Zone Structure in Two- and Three-Dimensions

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Abstract: A significant body of research exists in the study of Richtmyer-Meshkov instability (RMI) for interfaces with single sinusoidal mode perturbations. However, in applications where RMI is encountered (ICF and supernovae are two important examples) the perturbations will typically be composed of a broad spectrum of modes with random amplitudes and phases. Compared to the single-mode case, relatively little is known about the behavior of RMI with these random initial perturbations. One particularly interesting aspect of RMI in the random-interface regime is that while the mixing zone development is inherently three dimensional, most numerical simulations are done in two-dimensions due to computer memory and time constraints. This restriction to two dimensions has the potential to significantly affect instability growth and in this work we explore the role that dimensionality plays in the dynamics of RMI.
LANL's RAGE adaptive mesh eulerian code running on the massively parallel ASCI Bluemountain machine is used to simulate random-interface RMI in both 2D and 3D. We present measurements of mixing zone growth rates and compute several important statistical quantities from the simulation data, identifying significant differences between the 2D and the 3D results. The effects of reshock, due to reflection of the transmitted shock from a downstream wall, will be illustrated. We will also describe the geometric structure of the mixing zones using such tools as fractal analysis, size distributions of coherent structures, and interfacial length/area dynamics. Again, comparisons will be made between 2D and 3D results.
We are unaware of three-dimensional RMI experiments with well-defined initial conditions. We will, though, use whatever experimental data is available for guidance and to help us judge the quality of our calculations.
Based on the results of our analysis of the computations and experiments we will discuss the role that dimensionality plays in RMI growth and comment on the validity of using two-dimensional simulations in the inherently three-dimensional random-interface RMI.

Abstract number:123

Analytical Prediction for the Late Time Behavior of Interfacial Fluid Mixing

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Abstract: Surface tension is an important factor in the dynamics of unstable interfacial fluid mixing. It can change not only the quantitative behavior of the unstable interface, but also the qualitative behavior of the unstable interface. We develop a nonlinear theory for the unstable interfacial fluid mixing with surface tension and provide an analytical expression for the terminal bubble velocity with surface tension. The theoretical predictions are in good agreement with the results from numerical computation using a boundary integral method.

Abstract number:124

Low-Symmetric Bubbles in Rayleigh-Taylor Instability

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Abstract: We study the "bubble problem", the highly non-linear stage of the Rayleigh-Taylor instability. For the first time the problem of dimensional crossover in RTI (or relations between the systems of 3D and 2D bubbles) is considered theoretically [1,2]. The problem is formulated for an ideal fluid of infinite height and without surface tension, and the flow is three-dimensional and periodic in the plane normal to gravity. To solve the problem analytically, we use asymptotic expansion near the bubble top in terms of time-dependent correlation functions, and our theoretical approach is based on the principles of the group theory.

We show that the symmetry of 3D flow is an important factor for the bubble problem. 3D steady motion can be generated at highly non-linear stages of RTI, if the flow is invariant with respect to a symmorphic symmetry group posing inversion (for example, hexagonal, square or rectangular symmetry in the plane normal to gravity). There is a family of steady solutions, and the flow symmetry determines the number of the family parameters. We establish local stability criteria for the steady solutions family [1].

In accordance with this local stability analysis, high-symmetric 3D steady flows in RTI are stable. For these flows, the unique steady solution is the Hopf's bifurcation, and it has a "universal" form: $R=4/k$ and $v=1.05(g/k)^{1/2}$, where R and v are the curvature radius and the velocity at the top of the steady bubble and k is wave vector. With lowering of the flow symmetry, the steady bubbles conserve a near-circular contour and become wider, jets are narrowing and steady velocity increases. These changes are significantly large to be measured (up to ~30%) [1].

Contrary, for low-symmetric 3D steady bubbles in RTI (for example, rectangular lattice with an arbitrary value of aspect ratio k_y/k_x), there is no a preferable stable form and no stable steady solutions exist. The mode associated with 3D-2D transition becomes positive at vanishing values of aspect ratio $k_y/k_x \ll 1$, and the dimensional crossover in RTI is discontinuous. We show that topological structure of 3D and 2D bubbles in RTI is different, and 3D steady bubbles cannot be transformed into 2D steady bubbles in a continuous way. 3D bubbles in RTI tend to conserve a near-circular contour with $R_x/R_y \sim (k_y/k_x)^2$, where R_x and R_y are curvature radii at the bubble top, the independent parameters of the solutions family. For low-symmetric bubbles this tendency results in the flow instabilities, such as splitting for "elongated" bubbles with $R_x/R_y < (k_y/k_x)^2$, or merging for "squeezed" bubbles with $R_x/R_y \geq (k_y/k_x)^2$ [1,2].

Although, in degenerate 2D case, our theory eliminates discrepancies between previous theoretical approaches [1], our analytical results show that in experiments on RT instability NO bubbles are 2D. A large-scale noise immediately converts the system of "approximately" 2D bubbles into a 3D one followed by the 3D bubbles splitting. This instability justifies the flow scales and eliminates anisotropy in the directions normal to gravity [1,2].

We analyze the global flow instabilities in terms of the symmetry theory and show that for 3D bubbles in RTI, there is a mechanism of self-organization. Both merging (inverse cascade) and splitting (direct cascade) have the principal importance for the system dynamics. These processes provide a near-circular contour of RT bubbles and isotropy of the flow in the plane normal to gravity [2].

We discuss appropriate statistical model of turbulent mixing in RTI.

Agreement with existing experimental and numerical data is good.

References

1. S.I.Abarzhi, "Stable steady flows in Rayleigh-Taylor instability", Phys.Rev.Lett.89, 1332 (1998)
2. S.I.Abarzhi, "Low-symmetric bubbles in Rayleigh-Taylor instability", to be published

Abstract number:125

Simulations of Two-Scale and Double-Shocked Richtmyer-Meshkov Instability

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Abstract: We have performed and analyzed simulations of two Richtmyer-Meshkov instability problems. The first entails subjecting an interface with single-initial-mode three-dimensional perturbation to two shocks. Simulations performed at higher resolution than we reported previously [1] support the previous conclusion that the second shock is particularly effective at producing a highly turbulent state. Analysis of the simulations indicates that the baroclinic and vortex stretching terms dominate the vorticity production during the second shock passage, and are thus likely candidates for the destruction of coherent bubbles and spikes. The second set of simulations is of a single-shocked interface with a two-scale initial perturbation, qualitatively similar to the Vetter-Sturtevant shock-tube experiments [2]. A series of increasing-resolution 3-D simulations have been performed, up to a maximum resolution of $2048^2 \times 1920$. A corresponding 2-D sequence has also been performed, along with a strictly periodic single mode simulation (at the shorter of the two scales). Visualizations suggest a transition from well-defined bubbles and spikes to turbulent flow as the effective Reynolds number (related to numerical dissipation) is increased, and the 2-D/3-D comparisons indicate the prevalence of reverse and forward cascades, respectively.

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References

1. R. H. Cohen, W. P. Dannevik, A. M. Dimits, et al., in Physics of Compressible Turbulent Mixing, 6th Intl. Workshop on the Physics of Compressible Turbulent Mixing, Jourdan and Houas, eds., p. 128 (1997).
2. M. Vetter, B. Sturtevant, Shock Waves 4, 247 (1995).

Abstract number:126

Sensitivities of Mixing Rates Due to Rayleigh-Taylor Instability

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Abstract: Three-dimensional simulations of turbulent mixing by the Rayleigh-Taylor (RT) instability in the near-incompressible regime have been completed using the piecewise-parabolic-method (PPM), [1] both as converged DNS with Navier-Stokes (NS) dissipation and as "pure PPM" without NS dissipation. The observed mixing rates are lower than those seen in experiments [2] and roughly consistent with some other simulations in the literature [3]. However, switching off the Navier – Stokes dissipation, so that the dissipation is entirely numerical and due to the PPM algorithm, and reducing the spatial scale size of the initial perturbations both result in a *decrease* in the mixing rate.
Other simulations [4] yield mixing rates in agreement with the experiments cited above. These discrepancies motivate further simulation studies, which are underway and some of which will be reported, that attempt both directly to resolve this discrepancy and to more broadly explore the various sensitivities of the mixing rates to both physical and numerical aspects of the simulation models. These aspects include initial conditions (broad spectra with and without cutoffs vs sharply peaked spectra; whether or not the spectra contain modal components that are not resolved by the numerics or are in the dissipation range associated with the dissipation), the form of the dissipation (numerical or true Navier Stokes), whether there is inter-species diffusion (in the multi-species case) or thermal or density diffusion (in the single-species case), effective Reynolds' number, boundary conditions and system aspect ratio, and compressibility.

*This work was performed by LLNL for USDoE under contract W-7405-ENG-48.

References

1. P. Colella and P.R. Woodward, JCP **54**, 174 (1984).
2. K.I. Read PhysicaD **12**,45 (1984); G. Dimonte et al., Phys. Rev. **E54** (1996).
3. D.L. Youngs, Laser and Particle Beams**12**, 725(1994).
4. J. Hecht et al., Laser and Particle Beams, **13**,423 (1995); O. Schilling et al., this meeting.

Abstract number: 127

Experiments on the Incompressible Richtmyer-Meshkov Instability

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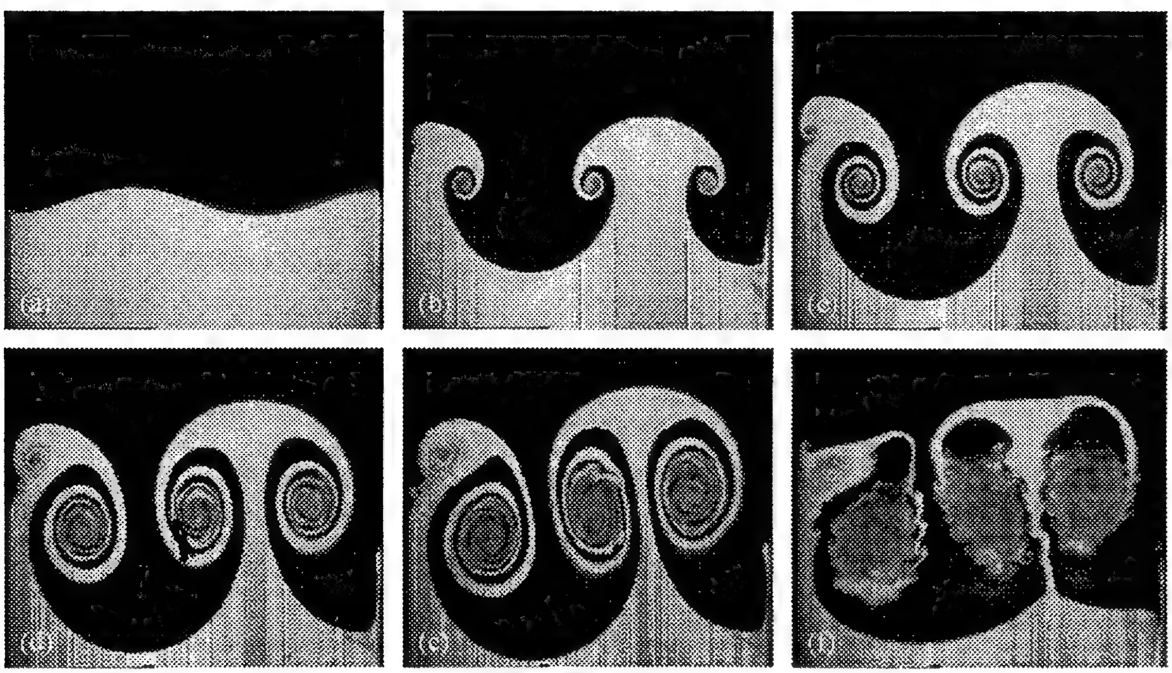
Abstract: Experimental results will be presented in which Richtmyer-Meshkov instability is produced by the impulsive acceleration of a system of two miscible liquids (a salt/water solution and a water/alcohol solution). The liquids are contained within a clear plastic box that is mounted to a rail system which constrains its motion to the vertical direction. The container is raised to a prescribed height and a controlled initial surface shape is given to the system by oscillating the container in the horizontal direction. The container is then released and falls vertically until it bounces off of a stationary spring producing an impulsive acceleration. Results will be presented from an entirely new apparatus that makes use of a retractable spring and a longer set of rails to obtain longer experimental run times. After impact the spring retracts out of the way so that the tank passes freely by instead of bouncing a second time as in previous experiments. The tank is finally brought to rest by a shock absorber at the bottom of the rail system. In addition to longer run times, other improvements now allow larger accelerations and initial perturbation amplitudes, thus significantly increasing the instability growth rate. Below is a sequence of planar laser induced fluorescence images from an experiment with a dimensionless initial amplitude (product of initial amplitude and wave number) of 0.35. The pictures show the development of vortices similar to previously reported results having smaller initial amplitudes and impulse strengths. However, in this case the development of a secondary instability can be observed near the center of vortices which ultimately spreads throughout the vortex cores. The fluids receive a second acceleration in frame (f) as the container is brought to rest at the bottom of the rail system.



Abstract number:128

Statistical Properties of Rayleigh-Taylor Mixing

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Abstract: Direct numerical simulations (DNS) of Rayleigh-Taylor mixing of two incompressible miscible fluids have been performed on the ASCI Blue Pacific computer at LLNL. The DNS utilizes spectral/Pade representations of spatial derivatives in conjunction with a third-order, Adams-Bashforth-Moulton time integration scheme. The temporal evolution of the mixing layer and the intensity of mixing are presented and compared to experimental data. In addition, the time-dependent structure of the mixing layer is studied by computing the horizontal average of terms in the fluid evolution equations. The fields are decomposed into mean plus fluctuating quantities, and the resulting evolution equations for the mean density, momentum, and vorticity, as well as the evolution equations for the turbulent density variance, kinetic energy, and entropy, are studied. Implications of the results for the development and testing of subgrid-scale models appropriate for large-eddy simulation of Rayleigh-Taylor instability-induced turbulent mixing are discussed.

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Department of Energy by Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48, and was supported by the Accelerated Strategic Computing Initiative (ASCI) Program.

Abstract number:129

A Two-Shock Richtmyer-Meshkov Instability Experiment on NOVA

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Abstract: An experiment to examine the effect of a second, counter-propogating, shock on the Richtmyer-Meshkov instability in the high Mach-number regime is being performed on the NOVA laser. The novel design for this experiment uses two half-hohlraums mounted at each end of a 2.4–mm shock tube. Four beams from NOVA enter each half-hohlraum and a shock is ablatively driven into brominated-polystyrene. On one side the shock ($M \cong 15$) traverses a machined perturbation between the high-density brominated-plastic and low density carbon foam, which initiates a Richtmyer-Meshkov instability. The counter-propogating shock traverses the shock tube and impacts the evolving mix region, which is expected to enhance the growth rate and lead to an accelerated transition to turbulence.

A novel design for the shock tube, which is roughly twice the diameter of previous shock tubes on NOVA, includes a thin strip of high-opacity, brominated plastic sandwiched between two layers of low-opacity, density-matched material. The perturbations are machined in a direction perpendicular to the high-opacity strip. This restricts the viewing region to the center of the shock-tube, which effectively removes line-of-sight shock curvature effects from the experiment. The spatial extent of the mix zone is diagnosed via side-on radiography.

Initial results show clear images of the spikes and bubbles following the initial shock and just after the passage of the second shock. The experimental plan to be carried out on NOVA is to examine the growth of the mixing region resulting from the first and second shocks interacting with one amplitude of initial (pre-shock) perturbations of $A_0 = \pm\ 5\mu m$ with $\lambda = 100\ \mu m$ wavelength. Comparison of simulation to data gives good agreement, and details of the simulations and comparisons to theory will be presented.

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Abstract number: 201

On Corpuscular Approach to Turbulent Flow Simulation

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Abstract: Simulation of complex multidimensional turbulent flows in large-scale systems, including with material mixing at interfaces, is an urgent problem. A comprehensive direct numerical simulation of the flows is yet impossible even with using modern super-computers. A method to solve the problem is large vortex hydrodynamical computation self-consistent with taking into account small-scale vortices inside computational cells with subgrid simulation. Efficiency of the method depends on how completely the subgrid model describes the values averaged inside the cell: material mixing, turbulent energy, material, energy and momentum flows through the cell boundaries. A natural approach to construction of the model is the corpuscular one. In particular, this is known as the point vortex model. A difficulty in development of the models relates to complexity of describing the collective interaction of the "particles".

This paper uses a phenomenological approach for assessment of the form of the "particle" transport kinetic equation and interaction constants.

A simplest and major turbulent flow type, i.e. submerged jet, is considered for the first step.

Published experimental data for submerged jet in incompressible fluid were studied to show that the averaged jet characteristics, i.e. profiles of jet velocities, velocity pulsations, jet shape, are described with a solution to the linear kinetic equation for particle propagation from a radiant source in medium with scattering at small angles.

Qualitative consideration of turbulent flow direct numerical simulation results published by some investigators allows to conceive that the particles are vortex formations, i.e. rings, filaments and their fragments. The observed turbulent jet pattern is a manifestation of dynamics of the formation transport with scattering, fragmentation, absorption. An approximate self-similar solution to the linear kinetic equation is used to construct an analytical formula describing the field of average velocities and their pulsations. Effective ranges of the "particles" in scattering and absorption are estimated and compared with the experimental data.

An important conclusion from the above phenomenological consideration is that of the transport kinetic process linearity. This allows to construct the solution for various flows using the superposition principle.

The approach can be a starting point for computing complex time-dependent flows, for the subgrid model construction at numerical solution of large-scale problems. As a demonstration of capabilities of the proposed method, an estimating solution is constructed for cumulative collapse of the cavity in material with assessment of the effect of the turbulence due to spherical cumulation instability.

By the example of incompressible fluid it is shown that there is no unlimited cumulation. This is because of the effect of initial microperturbations in a thin near-wall layer. At the cavity convergence the perturbation energy is comparable to radial motion energy in a cavity whose sizes are comparable to the final cavity sizes. Thereby the energy cumulation at the center can become reduced.

Approximate estimations for compressible fluid are made.

Abstract number: 202

Evolution of Mixing Region of Gases of Different Densities During its Accelerated or Decelerated Motion

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Abstract: One-dimensional model for motion of the mixing region of gases of different densities in the setup IU-03 is given in the paper.
The experimental results on excitation and development of the mixing region moving either with acceleration under the influence of the incident compression wave or with deceleration resulted from the reflected compression wave, are presented. Experimentally obtained density and thickness distributions within the mixing region are compared with those for the one-dimensional model.
Two-dimensional numerical simulations of the Rayleigh-Taylor instability excitation and development during the accelerated motion of the mixing region are described.

Abstract number: 203

Investigation of Richtmyer-Meshkov Instability in Layered System

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Abstract: A series of shock-tube experiments to study the Richtmyer-Meshkov instability for the case of a layered system has been carried out. A thin gas layer of intermediate density ρ_B (gas B) was disposed between two gases, one of which had a low density ρ_A (gas A) and the other one had a high density ρ_C (gas C). A shock tube driven was divided into three parts by two thin membranes modeling initial interfaces on A/B (K^0_{AB}) and B/C (K^0_{BC}) boundaries. The initial thickness Δ of gas B layer was one of the following values: 20, 37, or 56 mm. The initial interfaces on A/B and B/C boundaries (K^0_{AB} and K^0_{BC}) used in all the experiments were two-dimensional perturbations of sinusoidal shape (2D) with wavelength λ=36 mm and amplitude measured from peak to peak of sinusoid a_0=10 mm. The visualization field was located from 3.5 to 113.5 mm, or from 220 to 330 mm downstream from the second membrane fastening plane (on B/C boundary). The initial pressures of working gases in all the volumes of the driven were 0.5 atm. A maximum distance $L(X)$ (along the driven axis) separating shock-compressed flows of pure gases A and C was determined at different thicknesses of gas B layer. The Mach number M_0 of the incident shock was 2.6±0.2. The phenomenon of the instability suppression in layered medium for the following gas system: A — He, B — Ar, C — Xe was experimentally found in the previous study [1]. In the present study the influence of the parameters of the intermediate layer on the mixing region thickness was under investigation. As an intermediate gas B we used Ne, Ar, and Kr. $L(X)$ was compared with previously obtained results on the penetration depth L_{2D} of shock-compressed He into Xe for a shock passage through 2D interface with wavelength λ=36 mm and amplitude a_0=10 mm without an intermediate layer [1,2].

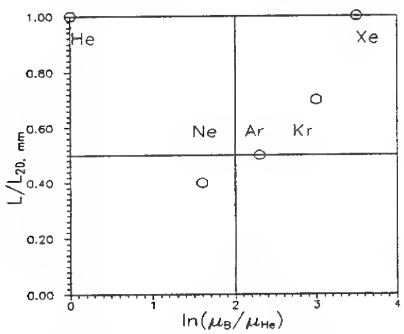

Fig.1. The mixing region thickness $L(X)$ vs type of the intermediate gas at layer thickness 37 mm (X=300 mm)

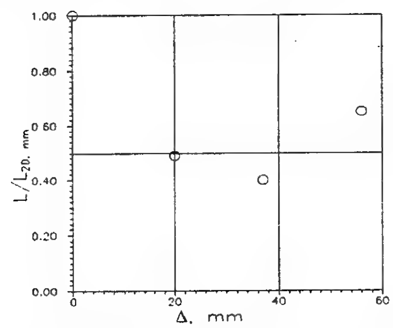

Fig.2. The mixing region thickness $L(X)$ vs Ne layer thickness (X=300 mm)

Fig. 1 presents the mixing region thickness $L(X)$ for different intermediate gases at layer thickness 37 mm (~λ). As seen, minimum thickness of the mixing zone is observed for Ne intermediate layer at Δ~λ. Here Atwood numbers on He/Ne and Ne/Xe boundaries are 0.667 and 0.735, respectively. At X=8λ nearly 2.5-fold reduction of the mixing region thickness is observed as compared to that for a shock passage from He directly into Xe.

Fig. 2 presents values L/L_{2D} at different thicknesses of Ne layer. It was observed that instabilities on K_{AB} and K_{BC} evolved independently on the initial stage if Δ>1.5λ, but even in this case the mixing region thickness is less than a sum of 2D mixing region thickness and thickness of the compressed Ne layer. Reduction of the layer thickness to Δ~λ or less and its strong compression, caused by the distorted refracted and reflected shocks propagating inside the layer as well as by multiple reverberations of compression and rarefaction waves, leads to significant reciprocal influence of K_{AB} and K_{BC}, and, as a result, to deceleration of the mixing region growth rate. The minimum thickness of the mixing region is observed at the layer thickness Δ~λ.

References

1. Aleshin A.N., Lazareva E.V., Sergeev S.V., Zaytsev S.G. (1998) On the Problem of Richtmyer-Meshkov Instability Suppression. Doklady Akademii Nauk 363, 2:
2. Aleshin A.N., Zaytsev S.G., Lazareva E.V. (1995) Refraction of a Shock Wave Through a Sinusoidal Discontinuous Interface Separating Gases of Different Densities. Proceedings Of The 19th International Symposium On Shock Waves: 255-260.

Abstract number: 204

Richtmyer-Meshkov Instability Evolution at Unharmonic Perturbation of an Interface

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Abstract: A series of shock tube experiments to study Richtmyer-Meshkov instability evolution for the case of unharmonic initial perturbation of sinusoidal shape with different wavelengths and amplitudes, disturbed by shock passage was carried out for two couples of inert gases: He - Xe (the Atwood number At=0.941, the Mach number $M_0 \approx 2.7$) and Ar - Xe (At=0.533, $M_0 \approx 3.5$). The initial two-dimensional (2D) interfaces were modeled with a thin polymeric film, 1.5 - 3 μm thick, glued onto plastic frames.

We studied reciprocal influence of perturbations which had both equal and different values of curvature a_0/λ (a_0 and λ are the initial perturbation amplitude and wavelength).

Analysis of the experimental data indicated that the reciprocal influence of neighboring perturbations of the same initial curvature a_0/λ has expressed in 30% perturbation growth as compared to the single 2D perturbation, i.e. if the distance between neighboring perturbations exceeded 3λ [1].

Results of the data processing indicate that significant reciprocal influence of the perturbations, which had parts of different curvature a_0/λ is observed in the case of the perturbation consisted of two parts: the lower part is a sinusoidal perturbation with wavelength λ = 72 mm and amplitude a_0= 10 mm, the upper part is a harmonic sinusoidal perturbation with wavelength λ = 12 mm and amplitude a_0= 10 mm (a_0/λ = 0.83). This influence is expressed in deceleration of the perturbation growth rate as compared to the growth rates of its any parts. Such an effect is observed both for Ar - Xe and He-Xe couples, but it is not so evident in the latter case due to large value of the Atwood number.

Reference

1. Sergeev S.V., Aleshin A.N., Lazareva E.V., Zaytsev S.G. Experimental Study Of Richtmyer-Meshkov Instability On Interface Consisted Of One Or Several Perturbations. Proceedings of The International Conference «IV Zababakhin Scientific Talks», Snezhinsk, Russia, 1995.

Abstract number: 205

Influence of Turbulent Mixing on Dynamics of Liquid Layer Accelerated by Compressed Gas

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Abstract: The paper presents results of experimental study how turbulent mixing (TM) at unstable boundary of liquid layer accelerated by pressure of compressed gas influences on character of the layer dynamics and efficiency of following-on transition of energy to gas layer compressed by liquid layer.

Tests of two types were carried out in the following geometries:

a) *rigid wall - compressed gas 1 - liquid layer - gas 2* (at atmospheric pressure and room temperature). As gas 1 accelerated layer under study, we used compressed helium at room temperature («cold» gas) or greatly heated products of explosion of an acetylene-oxygen mixture («hot» gas) [1];

b) *rigid wall - compressed gas 1 - liquid layer - compressed gas 2 - rigid wall.* In this case gas 1 is products of explosion of an acetylene-oxygen mixture, gas 2 is air at room temperature and atmospheric pressure.

At acceleration of liquid layer by pressure of compressed gas, the Rayleigh-Taylor instability and turbulent mixing is growing at the layer boundary. In both cases gas 2 was separated from liquid layer by a rigid plate preventing growth of instability and TM.

Studies were carried out basing on comparison between dynamics of layers with similar weights made of:

- water,
- jelly of water solution with low concentration (4.4%) and
- layers with completely suppressed mixing (due to layer strength).

It was revealed in the first-type experiments that TM can result in both increase of layer velocity (due to decrease of effective mass of layer) and its drop (due to cooling down of «hot» compressed gas because of growth of heat transition from gas to liquid). Efficiency of energy absorption by liquid layer decreases.

The second-type experiments show that energy losses can be very significant (tens of percents).

The work is carried out with support of International Scientific Fund (grant NM4000) and LANL, USA (contract B70040006-35 SOW 018).

References

1. I.G. Zhidov, E.E. Meshkov, N.V. Nevmerzhitskii. Influence of turbulent mixing on acceleration of layers with various strengths. // VANT, ser. Theory and Appl. Phys. Issue 1-2, 1996.

Abstract number: 206

Influence of Turbulent Mixing on Transformation of Energy of Moving Liquid Layer into Internal Energy of Compressed Gas

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Abstract: Experimental study was carried out in order to reveal how turbulent mixing (TM) influences on transformation of energy of moving liquid layer into internal energy of gas compressed by this layer.

The work is a continuation of earlier studies of TM influence on processes of acceleration of liquid layers by compressed gas [1,2].

The experiments were carried out in the following set-up: *rigid wall - compressed gas 1 - liquid layer - compressed gas 2 - rigid wall.* Gas 1 was separated from liquid layer by a thin rigid plate preventing from TM growth. The both gases were gas explosive mixtures with various formulations, namely, an acetylene-oxygen mixture $C_2H_2+2.5O_2$ (gas 1) and a $2H_2+O_2$ (gas 2). Pressure of explosion products of mixture $C_2H_2+2.5O_2$ is approximately two times higher than pressure of mixture $2H_2+O_2$. After simultaneous initiation of detonation of both mixtures, the liquid layer starts compressing hydrogen-oxygen mixture explosion products due to pressures difference.

Compression of gas 2 by liquid layer at the stage of layer deceleration is followed by growth of the Rayleigh-Taylor instability and TM at the liquid layer-compressed gas boundary. Gas 1 was separated from liquid layer by thin rigid plate preventing from TM growth at the stage of layer acceleration.

Fragmentation of liquid in the TM zone results in sharp increase of heat exchange from hot gas to layer substance and, as a consequence, both quantitative and qualitative changes of dynamics of gas 2 compression (comparing to the case when TM is suppressed).

Studies were carried out basing on comparison of dynamics of water and jelly layers. Their motion was followed by growth of TM and layers with completely suppressed mixing (due to layer material strength).

At some conditions the authors observed higher compression of gas by liquid layer than in the case of rigid layer (up to ~1.5 times).

The summarized presented experimental data are of interest, in particular, as a test for numerical techniques aimed to describe multiphase non-stationary flows followed by TM and heat exchange.

The work is carried out with support of LANL, USA (contract B70040006-35 SOW 034).

References

1. I.G. Zhidov, E.E. Meshkov, N.V. Nevmerzhitsky. Influence of turbulent mixing on acceleration of layers with various strengths. // VANT, ser. Theory and Appl. Phys. Issue 1-2, 1996, pp. 20-23.
2. I.G. Zhidov, E.E. Meshkov, N.V. Nevmerzhitsky, I.G. Pylev, E.A. Sotskov. Influence of turbulent mixing on dynamics of liquid layer accelerated by compressed gas. // Paper for this workshop.

Abstract number: 207

Numerical Simulation of Heat Exchange Processes in Zone of Turbulent Mixing with Use of k-ε Model of Turbulence

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Abstract: Capabilities to take into account heat processes in the zone of turbulent mixing (TMZ) are demonstrated using numerical technique EGAK-T based on 2D semiempirical k-ε model of turbulence [1].

Set-up of calculations corresponds to the experiments carried out by the technique of liquid layers [2] - compression of explosion products by moving liquid layer. Dynamics of hot gas compression in this case differs qualitatively from compression by a rigid piston. Calculation results appear to be sensitive to choosing of fragmentation model. Description of fragmented liquid reduced to effective size of drops. If this value is specified as constant in time, even qualitative agreement with experimental relations is not obtained at wide range of drop sizes. In the case when drop size is assumed to be varied according to relation describing peculiarity of flow and containing one empirical parameter, one can manage to agree the calculation results both qualitatively and quantitatively.

To describe heat exchange from gas to a separate drop, simple model containing one semiempirical dimensionless constant - Nusselt number is used.

Calculation results illustrate possibility to use 2D semiempirical k-ε model of turbulence at large differences of densities. Comparative analysis of numerical and experimental results of hot gas compression by liquid layer showed high substantiality of the experimental set-up [2] as a test for numerical techniques.

References

1. Yu.V. Yanilkin, V.V. Nikiforov, G.V. Zharova. «Model with two equations and technique to calculate turbulent mixing in 2D compressed flows», VANT, ser. MMPF, issue 4, 1994, pp. 79-84.
2. M.V. Bliznetsov, I.G. Zhidov, E.E. Meshkov, N.V. Nevmerzhitskii, E.D. Sen'kovskii, E.A. Sotskov, V.A. Til'kunov. Influence of turbulent mixing on transformation of energy of moving liquid layer into internal energy of compressed gas. Paper for this workshop.

Abstract number: 208

3D Numerical Turbulent Mixing Zone Near Interface between Two Media

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Abstract: The problems related to direct numerical simulation of turbulent mixing zone occurring due to hydrodynamic instability (R-M instability) under numerous passage of a shock through an interface between two media, are reported.

A series of 2D and 3D computations allowed us to study the effect of wavelength and amplitude of small–scale noise perturbations at initial interface on the width of mixing zone.

Numerical results of the R-M instability growth at non–regular shock diffraction at the interface, are presented.

Numerical simulation was performed using 2D and 3D parallel codes NUT for multiprocess station PARSYTEC CC -32.

Abstract number: 209

The Evolution Model of a Mixing Zone Growth in the Case of a Complex Initial Spectrum of Perturbations

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Abstract: The generalization for the model [1] in terms of imposed perturbations with the different "amplitude / wavelength" ratios is presented. The theoretically obtained coefficients for the time dependent law of a turbulent layer thickness growth are compared with numerical predictions [2] as well as with the experimental data.

References

1. N.V.Zmitrenko, N.G.Proncheva, and V.B.Rozanov. The evolution model of a turbulent mixing layer. // Preprint P.N.Lebedev Physical Institute, No.65,1997.
2. V.F.Tishkin, V.V.Nikishin, I.V.Popov, and A.P.Favorsky. The difference schemes of three dimensional gas dynamics for the problem of the Richtmyer-Meshkov instability development. // Mathematical Modeling, 1995, Vol.7, No,5, pp. 15-25 (in Russian).

Abstract number: 211

Direct Numerical Simulation of Developed Shear Driven Turbulence

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Abstract: The work is devoted to direct numerical simulation of turbulent mixing by shear driven instability at an interface of two plane-parallel gas flows. The work presents the results obtained in 2D simulations of turbulence being developed at the interface of two almost incompressible gases using the MAX program package. Spatial and temporal evolution of the turbulence zone resulted from shear driven instability is studied. We calculated the constant of shear driven turbulence mixing and investigated how the rate of turbulence zone growth depended on density difference of mixed fluids. Heterogeneity coefficient of the mixture was calculated for all considered density differences.

Abstract number: 212

Coefficient of Heterogeneity in Turbulent Mixing Zone

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Abstract: The paper considers the equation for heterogeneity coefficient within turbulent mixing area in the approximation of big Reynolds numbers and small Mach numbers. A mechanism is studied of the heterogeneity coefficient dissipation due to molecular diffusion. The Kolmogorov's hypothesis on developed turbulence is used to calculate a dissipative term. The model presented allows to take into account the heterogeneity degree in *LV*- and *KE*-models of turbulent mixing. A system of equations allowing to calculate directly the heterogeneity degree is derived for the case of *LV*-model with the turbulent diffusion coefficient which is constant over the turbulent mixing area. A self-similar solution is derived for the heterogeneity coefficient which is in good agreement with the results of experiments and direct numerical simulations. The heterogeneity coefficient averaged over the mixing area is shown to depend weakly on the density drop between the mixing materials. Thus, it is k_H=0.25 at the drop n=1-3, and at the drop n=20 - k_H=0.23.

Abstract number: 213

On a Coupled Development of MHD Instabilities of Rayleigh-Taylor and Kelvin-Helmholtz Types in Nonuniform Gas-Plasmas Flows

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Abstract: The problem of hydrodynamic stability of high-conducting plasmoid moving in magnetic field under conditions of intensive flow around it by non- or low-conducting gas is considered. The main attention is paid to study of the process of simultaneous development of MHD instabilities of Raylegh-Taylor (RTI) and Kelvin-Helmholtz (KHI) types at the interface between plasmoid and surrounding gas. The analysis of the interaction of these instabilities and differences between results of their individual and coupled development is conducted.

The analytical solutions describing development of the RTI in compressible and incompressible fluids have been obtained in the framework of linear theory. An one-dimensional layer with elevated conductivity dividing two semi-infinite regions of weakly conducting fluid has been assigned as background (undisturbed) flow. The dispersion curves have been constructed, the analysis of influence of such factors as background flow parameters, intensity of MHD interaction, layer thickness, etc., on instability increments has been carried out. The estimation of maximum instability mode resulted from viscous effects has been obtained. This estimation has been used to determine the boundaries of feasibility of inviscid physical model.

The nonlinear stage of individual and coupled development of instabilities has been investigated numerically. The time-dependent two-dimensional model based on solution of Euler gasdynamic equations has been created. Two versions of initial flow structure have been used in calculations. The one-dimensional background flow has been assigned as in linear analysis, the two-dimensional one has been result of the preliminary calculations of flow around plasmoid. In the former case a disturbance introducing in the background flow has been periodic with varied wave length and amplitude, in the latter case a disturbance has been single with varied type and position along the plasmoid surface.

Fundamental difference between the results of linear and nonlinear analysis has been revealed. In particular, the increment of the RTI development at nonlinear stage is one-two order of magnitude less than that predicted by linear theory and rather weakly depends on initial disturbance mode. In linear analysis the coupled development of the RTI and the KHI is determined by simple summing of the two effects in the expression of wave increment, whereas in nonlinear case the mutual influence of the instabilities leads to essential alterations in their development, in particular, results in intensive "layer-by-layer" destruction of the plasmoid surface.

Abstract number: 214

Second-Order Modeling of Variable-Density Turbulent Mixing Layer Using Algebraic Equations for Second Moments

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Abstract: Favor density-weighted averaging method is used to develop a variant of second-order closure model for variable-density turbulent flows studies. The closure assumptions are based on the near constant density flow analogy and that provides adequate description of stratified surface layer data. Local equilibrium approximation results in algebraic Reynolds-stress, flux and other second order moments equations. Numerical simulations of variable-density 1D turbulent mixing layer forced by both shear and buoyancy effects are performed to test the reduced algebraic model. Comparison with experimental and DNS data available demonstrates the model validity. So simplified approach is an acceptable way to make cheaper 2D and 3D engineering models.

Abstract number: 215

Hydrodynamic Instability at High–Velocity Impact

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Abstract: There is an approach to Inertial Confinement Fusion (ICF), which is based on the use of a multiple shell target. The shells each perform their functions and are slightly spaced between themselves. With the implosion and heating of fusion fuel in the target center, the shells impact each other at a high velocity. The nonisotropic effects externally on the target and inaccurate fabrication assembly of individual components would cause the shells to impact obliquely or their distortion yet before impact. This may result in hydrodynamic instability on the impacted shell surface [1]. The surface would take on a wavy shape like that observed experimentally for explosive cladding and melding of materials [2]. The wave pattern depends on the relative impact velocity, the angle between and the physics of shell materials, and in many ways it suggests some stages of hydrodynamic instability such as Rayleigh – Taylor, Richtmyer–Meshkov, etc. This is because the behaviors responsible for instability development at the interface are determined by the shape and intensity of shock waves that occur there and the way they further interact with the encountered material and the waves from free surfaces.
The paper employs numerical simulation methods for ideal gas model to investigate into the hydrodynamic effects that result in the experimentally observed perturbations and discuss the mechanisms physically responsible for these, and describes specific computation results.
Applications of the numerical methods developed and the relevant computation data are not limited by the above–mentioned processes, as they may be also useful to develop protection of space vehicles or stations against high–velocity micrometeorites and dust particles, or in shock–tube production of diamonds and diamond powder, etc.

References

1. D.H. Kalantar, B.A. Remington, E.A. Chandler, J.D. Colvin, D.L. Griswold, R.E. Turner, S.V. Weber, L.G. Wiley "Nova experiments to investigate hydrodynamic instabilities in the solid state", Proceedings of 6th IWPCTM,p.p.232-237, 1997, Marseille
2. A.A. Deribas "Physics of explosive cladding and welding", "Nauka", 1980, Novosibirsk, Russia

Abstract number: 216

Some Methods of the Qualitative Theory of Parabolic Problems and Their Applications

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Abstract: Most of the recent models in mathematical physics involve nonlinear governing equations. In order to describe various phenomena, being observed in experiments, in the general frameworks of comparatively simple models, professionals introduce into the model degenerate leading terms, rapidly grow source terms, and other peculiarities. In case of evolution governing equation of diffusion type such nonlinear terms give rise to qualitatively new effects, like finite speed of disturbances propagation, development of the discontinuous step within finite time, and blowing-up of solutions, e.g. We mention here the so-called "derivative blowing up solutions", which remains bounded while their spatial derivatives grow to infinity within finite time. These solutions naturally arise studying digital image processing, turbulent heat and mass transfer, singularly perturbed problems, and other. Until now qualitative theory of the aforementioned effects is far from the level of well established knowledge of linear theory.

Such fundamental concepts as "Solutions in the Sense of Distributions" and "Solutions to Inequalities", rather than equations (variational inequalities, e.g.) are well known. Besides, some promising approaches to study far nontrivial non linear effects, which have been proposed in literature, are practically not in use, apart from some individual theoretical studies. Here we mention, just as an illustration, family of exact solutions to Navier-Stockes system (linear in vertical variable, which happens to be convenient to describe some vortex flows) and variational concept of solution to parabolic problems (which could be suitable studying derivative blowing up solutions).

During the last 30 years mathematical simulation have demonstrated a fair success in chemical technology. Modern technology is inconceivable without mathematical modeling and computation of chemical reactions, technological units, and the whole processes. Usage of mathematical tools makes it possible, for example, to reduce essentially a number of pilot plants of successive sizes. Modern chemical technology is mostly based on catalytic processes. In a number of cases the so-called fluidized bed reactors are exploited. In such reactors the gas phase mixture of reagents is blowing through a layer of catalyst particles at the speed of fluidization (solid particles move chaotically, like in a boiling liquid). For years models have been developed to describe in some sense chaotic movement of all particles. Finally it has been acknowledged that in view of prediction such basic parameters as rate of material conversion and thermal effect the much more simple "averaged" models give comparable results. In this way, instead of complicated multi particle dynamics, it has been proposed to study "two phases model". Such a model replace "chaotic hydrodynamics" with up-going and down-going flows (for both solid and gas phases) with a certain exchange coefficients. These models with a very few euristic coefficients are comparatively simple both for numerical study and qualitative analysis.

We would like to propose a discussion of possibility to use similar idea, based on simulation of complicated hydro/gasdynamics by averaged models with two oppositely directed flows for each component (with a certain exchange coefficients) to estimate, say, overall effects of mass and/or energy loss due to the turbulent mixing. Evidently, it is impossible to use directly models, already developed in chemistry. The point is to consider the general concept of such models.

Abstract number: 217

Rayleigh–Taylor Instability Growth on the Surface of a Friable Layer Driven by Compressed Gas

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Abstract: Being a stabilizing factor the strength of a medium (or of both media) in the same time does not completely prevent the growth of R-T instability and TM on unstable interface. The strength influence reduces to the occurrence of critical values of initial perturbation amplitude and wavelength; being exceeded it leads to perturbation growth freely. Friable material like typical elastics processes compression strength but unlike liquids, which have surface tension, it has not rupture strength. As a result, the R-T instability growth on the surface of a friable layer has some singularities.

These singularities are reported in terms of experimental data on driving a friable layer by a compressed gas. In these experiments, a layer of propylene particles (size ~ 0.5 mm) was accelerated by explosion products of acetylene–oxygen mixture in a square (4x4 cm) channel. In initial perturbation close to sinusoid in shape was imposed on the unstable layer surface.

A singularity in the strength properties of a friable material effects the asymmetrical behavior of the perturbation evolution from the very beginning.

For want of rupture strength (and even surface tension), the particles, being non – bounded and located on peaks of the perturbed surface (jets) fall down into the gas with acceleration g. In the region of valleys of the perturbed surface (bubbles), tightening the friable material occurs; the compression strength decelerates bubble growth at initial stage of the instability evolution.

Later, the layer swells and becomes pseudo–liquefied due to gas penetration into it. Then the process becomes similar to the instability growth on a gas–liquid interface.

Abstract number: 218

Experimental Simulation of Gas-Plasma Plane Interface Stability

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Abstract: Method of quick energy input [1] was used for experimental realization of quick homogeneous ionization of half-space area in front of plane shock wave in a channel. The conditions were organized that Rankine-Hugoniot relations on shock front were violated.

Shock tube with a special discharge section was used. Impulse volume discharge with gas pre-ionization by ultraviolet radiation from plasma sheets was involved [2]. The experimental setup consists of the discharge chamber mounted with a shock tube. Shock tube cross section was 24x48 mm. Two sidewalls of the chamber are the quartz windows. Another two walls are plasma electrodes. The flow pressure was 10-50 kPa, shock waves Mach numbers were 2-4. The discharge space voltage was changed from 25 to 40 kV.

The problem of shock wave stability has been analyzed theoretically, criteria of corrugation instability have been obtained (Dyakov, 1954, Landau and Lifshits, 1988), the conditions of shock front decay were discussed (Fowles and Houwing 1984). But the question is - how does the shock front look like when the stability criteria are violated in a real flow. This problem was not solved yet. It is assumed that the flow near the initial shock may be turbulized. The energy input time interval is much shorter than characteristic shock wave time intervals. The analysis of slit scanning obtained by means of electron optical cameras shows that the impulse discharge glow time is no more than 200 ns. So the ionization time interval is considered to be instant from the point of view of shock wave movement. Method of energy input being suggested allows to ionize homogeneously and quickly the half-space area in front of plane shock wave. The rectangular form of the discharge volume permits to simulate quick energy input in 1D, 2D, 3D flows. The method of energy input in shock tube allows: 1) to investigate experimentally problems of energy input influence on flow with shock waves; 2) to visualize three-dimensional gas flows with discharge radiation [2].

While propagating the plane shock wave in a test section the pulse discharge was initiated in nanosecond time interval. Volume discharge was switched instantly in front of the shock surface (in a low pressure area). So in time interval much less than shock front moves at 1 mm, shock becomes a gas-plasma interface. Rankin-Hugoniot equations on shock front were violated. Gas variables jump is determined by energy input in front of the shock. Shock front becomes unstable. Images of gas-plasma surface were recorded by method of visualization by volume impulse discharge [2]. Some time after the ionization moment (10-30 ms) the shock wave stratified structure was recorded by shadow method. Time–resolved pressure measurements were also conducted.

References

1. I.A. Znamenskaya. Method of Pulse energy input into gas flow. ICEFM III. Moscow 1997.
2. I.A. Znamenskaya. Discharge imaging technique for shock tube studies. In: Proc 21th Int Symp on Shock Waves. 1997. Keppel p. 88.

Abstract number: 219

Molecular Viscosity Influence on the Turbulent Mixing Zone Development

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Abstract: The interface of two fluids with various densities under homogeneous gravity is unstable if the gravity acceleration is directed from heavy fluid towards light one. The presence of initial disturbances results in turbulent mixing zone (TMZ) development. The limiting structure of TMZ is not affected by initial disturbances form while molecular viscosity influence on average flow and large-scale energetic eddies being negligible small. Purely viscous effects must be taken into consideration on early stage of TMZ development when viscous tensions are at least comparable with turbulent Reynolds stresses. Simple model is proposed in this paper which permits to examine qualitatively temporal process of TMZ development.

In described model TMZ is characterized by specific turbulent energy and density pulsation intensity averaged over zone and zone width. Turbulent energy and density pulsation intensity satisfy equations resulted from averaging of energy balance and mass conservation equations. Kolmogorov's hypothesis and dimensionality reasons are used for closure. Additionally it is suggested that large-scale energy eddies determine TMZ growth rate. Molecular diffusion and viscosity influence is accounted for in the model. The model is calibrated on possessing experimental information.

The main result of model calculations is that molecular viscosity exerts essential influence on TMZ development within a finite time interval $\approx 10\nu^{1/3}g^{-2/3}$ (ν - kinematics viscosity, g - characteristic interface acceleration). TMZ width is practically equal to its initial value while molecular diffusion being negligible small that is TMZ development delay occurs.

Abstract number: 220

The Radiation Hydrodynamic Effects in Two Beryllium Plates Joined by an Aluminum Braze

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Abstract: At present, the possible type of target for investigation on NIF facility is suggested to be the capsule consisting of two bonded together beryllium hemispheres. Non-uniformity caused by the bonded joint will initiate the two dimensional (2-D) effects during the shock wave passage through the joint. The aim of the study is to reach an understanding in terms of 2-D radiation hydrodynamics about the processes appearing at the joint of planar plates, which are accelerated on one side by X-ray irradiation.

The computational results of two consecutive shock waves propagation for two cases: with wide gap (L/W=15) and narrow one (L/W=150) will be presented. Here L and W are gap length and width, respectively. The analytical consideration of significant aspects of the problem is presented as well.

In simulations we consider a planar slab with thickness L=150 μm which consists from two semi-infinite beryllium plates bonded with aluminum filling the gap of width W=10 μm (wide gap) or W=1 μm (narrow gap). The slab is irradiated on the left by X-ray flow with the blackbody spectrum of the temperature time-varying according the specific low.

For wide gaps, when the gap width is much larger than the radiation free path in the material within the gap, the propagation of the shock wave in the vicinity of the joint between two beryllium plates becomes quasi-stationary. The second shock wave does not qualitatively change the flow pattern. Interface oscillations appear in the gap behind the shock front causing spatial perturbations of the interface with the characteristic wave length ≈12 μm. The shock wave in the center of the gap lags behind the shock wave in unperturbed beryllium by as much as ≈5 μm, which amounts to about half the gap width. It was shown that the initial perturbations of the gap change in shape but do not grow in amplitude.

For the narrow gaps, when the gap width is comparable to or less than the radiation free path in the material within the gap, preheating of the material within the gap a head of the shock front causes the preliminary expansion of the material within the joint and pre-compression of the material around the gap. The first shock wave motion is also quasi-stationary. The change of the flow direction initiates inherent oscillations of the gap, whose amplitude is comparable with the initial gap width. Therefore non-linear gap oscillations develop and drive Kelvin-Helmholtz instability. This leads to rapid heterogeneous mixing of the gap material with the surrounding matter. The shock wave in the middle of the gap leads the shock wave in unperturbed beryllium by ≈1 μm, approximately equal to the gap width.

Abstract number: 221

Comparative Study of Development of Periodical Perturbations in Liquid and Solid Media with Use of Jellies

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Abstract: The paper presents results of experimental study of comparative growth of 2D and 3D perturbations with amplitude a_0=0.5 mm, wave length λ_0=8 mm at unstable plane boundary between liquid layer and layer with strength (Rayleigh-Taylor instability). Studies were carried out with use of the jelly method. As the liquid layer, we used a low-strength jelly (with low concentration of C gelatin in water, C=4.4%), as the layer with strength – a jelly with high concentration (C=13.2%). In the cross-section the 2D perturbations had the shape of isosceles triangle with base λ_0 and height $2a_0$, the 3D perturbations had the shape of regular tetrahedral pyramid with base $\lambda_0 \times \lambda_0$ and height $2a_0$. The layers were accelerated by compressed gas at pressure of 8÷10 atm.

It has been obtained that in the frames of carried out studies the rate of 3D perturbations jets growth is higher than the rate of 2D perturbations jets growth in the case of the liquid layer, no significant difference is observed in rates of growth of jets of similar perturbations in layers with strengths.

These results can be used for testing of calculation techniques.

The work was carried out under the framework of ISTC Project № 029.

Abstract number: 222

Development of Local Perturbation at Unstable Boundary of Liquid Layer Accelerated by Compressed Gas

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Abstract: The paper presents results of experimental study of growth of local perturbation in the shape of conic protuberance at unstable boundary of liquid layer accelerated by compressed gas (Rayleigh-Taylor instability).
The liquid layer was simulated by a jelly with low concentration of C gelatin in water (C = 4.4%). Such jellies behaves as liquids at acceleration of them by pressure of compressed gas equal to 10 atm. Experimental results show that, with growth of the protuberance amplitude, one can observe growth of bubbles penetrating into jelly in the place of transition from cone to plane surface of the layer. Simultaneously with growth of protuberance amplitude its cross size is growing (contrary to jets of periodical perturbation).
The obtained results can be used for testing of calculation techniques.

Abstract number: 223

Calculational Analysis of NOVA Experiments on Compression of Liquid Deuterium up to 2 Mbar

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Abstract: Hydro-calculations of a target containing liquid deuterium under experimental conditions of the laser facility NOVA, 1997 have been conducted to study the equation of state for liquid deuterium up to 2 Mbar.
The laser radiation intensity was 10^{14}W/cm^2 during 8 ns. Analysis of the shock wave propagation dynamics in deuterium has shown the degree of its transience and considerable influence of two dimensionality on the average density in the compressed layer behind the shock front. The maximum deuterium density behind the shock front is about 0.8 g/cm^3.
Calculation of turbulent mixing at the interface between the Al pusher and deuterium has shown no noticeable effect of turbulence development.

Abstract number: 225

Effect of Turbulent Mixing in the Laser Radiation Absorption Zone on the Plasma Parameters and Propagation Behavior of a Flat Absorption Wave

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Abstract: Computational modeling of the propagation process of a subsonic laser radiation absorption wave in normal air has been carried out with turbulent mixing at the contact border taken into consideration. The intensity of continuous 1.315 μm laser radiation was varied within 10^7–10^9 W/cm^2. Calculations were carried out by using the 1D gas-dynamic code taking into consideration the ionization kinetics in the average ion approximation, spectral transport of plasma thermal radiation, its two temperatures, electronic and ionic conduction and turbulent mixing according to the Nikiforov and «k - ε» models.

The calculated results are compared to similar calculations without turbulent mixing on the absorption wave. Turbulent mixing is shown to have a considerable effect on the propagation behavior of the absorption wave and the thermodynamic properties of plasma.

Abstract number: 226

Influence of Layer of Solid Impurities on Growth of Turbulent Mixing in Liquid Layer Accelerated by Compressed Gas

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Abstract: The paper presents results of experimental study how layer of solid impurities influences on growth of turbulent mixing in liquid layer accelerated by compressed gas. As the liquid layer a jelly of gelatin water solution with low concentration of C ($C\approx4.4\%$) was used. Solid impurities were in the form of glass balls, cylinders, metal grids placed in the jelly layer at certain distance from unstable boundary. Distances between impurities in monolayer and size of the grid mesh were varied.

It is obtained that at certain conditions, when the zone of turbulent mixing or local perturbation is passing through the layer of solid impurities, velocity of their growth can significantly drop in some range of time. Then the growth velocity tends to the initial one.

Study results are of interest for searching the methods to suppress growth of Rayleigh-Taylor instability in certain conditions, and as a test for numerical techniques.

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Abstract number: 227

3D Bubbles in RTI: Analytical Investigation and Numerical Experiment

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Abstract: We study the highly nonlinear stage of the Rayleigh-Taylor instability for three-dimensional flow, and we use both numerical and analytical approaches to the problem and compare the results.
Numerically, we integrate the system of the Euler equations for compressible and inviscid fluids without surface tension. The numerical method is based on quasi-monotonic grid-characteristic scheme of second order of approximation [1]. The monotonicity is gained by switching between the schemes with central and oriented differences, as is done for incompressible flows in [2]. Neither a flux limiting procedure nor an artificial viscosity is used. The requirement of monotonicity provides a non-linear dissipative mechanism and, as a result, short-wave modes are damped. This numerical approach to the problem is formulated for the first time, and it is realized in the new compressible hydrocode E3D-HR.
Analytically, we consider the potential flow model for the Atwood number A=1. For 3D flow with "square" symmetry in the plane normal to gravity, there is the one-parameter family of steady solutions. We make a local stability analysis of the solutions [3]. We find that the stability region is narrow, the unique significant flow is the Hopf's bifurcation, and this limiting solution is close to Layzer-like solution [3]. The curvature radius of this steady bubble is $R=4/k$, and the velocity is $v=1.05(g/k)^{1/2}$. Our analysis shows that values of the bubble radius are more sensitive to the changes of the flow parameters than values of the bubble velocity [3].
In the computational experiment, we measure both the curvature radius R and the velocity v at the top of the rising bubble. Note that the accurate measurement of 3D bubble radius have never been done before. At the non-linear steady stage of RTI, we find $R=(3.6\pm0.3)/k$ and $v=(0.94\pm0.06)(g/k)^{1/2}$ for the Atwood number A=0.82 and the Mach number M=0.1. These values are in good agreement with the analytical results.
We present and discuss also other 3D simulations of RTI, that describe the development of 3D structures from 2D perturbations and the growth of the mixing zone for 3D random perturbations.
The numerical simulations were supported in part by the Russian Basic Research Foundation (the Project code 97-01-00931). The theoretical part of the work is supported financially by the Alexander von Humboldt Foundation.

References

1. A.M. Oparin, "Numerical simulation of Rayleigh-Taylor instability using quasi-monotonic grid-characteristic approach", to be published
2. O.M. Belotserkovskii, V.A. Gushchin, V.N. Konshin, "Decomposition method for investigating of stratified liquid flows with free surfaces", Zh.Vych. Mat. i Mat. Fiz. 27, 596 (1987)
3. S.I. Abarzhi, "Stable steady flows in Rayleigh-Taylor instability", Phys.Rev.Lett.89, 1332 (1998) and "Length scale for bubble problem in Rayleigh-Taylor instability", Phys.Fluids, 1999;

Abstract number: 228

Elastic Body and Fluid Interface Perturbation Evolution at Simultaneous Action of Constant and Pulsed Accelerations

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Abstract: When solving many scientific and technical problems, it is important to know laws of evolution of accelerated media interface perturbations. So, a complex approach including experiment, theoretical consideration, numerical study is used to study instability of accelerated interfaces (Raleigh-Taylor instability).

It is possible to find analytical solutions only for simplest problems. However; these allow to gain a better insight into the laws of the process and serve tests for numerical methods used for solving more complex problems. This paper analytically solves the problem of elastic body interface perturbation evolution at a simultaneous action of constant and pulsed accelerations. A similar problem for incompressible fluid is solved in paper [1].

It is interesting to note that the solution found by us for the simultaneous action of constant and pulsed acceleration is not a mere superposition of an exponentially growing solution corresponding to constant acceleration and vibratory one corresponding to pulsed acceleration. In the case of the simultaneous action of constant and pulsed accelerations the solution is a superposition of two exponentially growing functions $\mathrm{ch}\omega t$ and $\mathrm{sh}\omega t$, with the coefficient of $\mathrm{sh}\omega t$ depending on the velocity imparted from the pulsed acceleration.

It should be noted that the solutions found contain as a special case the solution to the problem of two incompressible fluids interface perturbation growth at simultaneous action of constant and pulsed accelerations obtained in [1]. The obtained solutions also contain the solutions of [2] for constant and pulsed accelerations acting separately.

References

1. Neuvazhayev V.E., Parshukov I.E. Studying instability of fluid interfaces under simultaneous action of pulsed and constant accelerations// Mat. Modelirovaniye, 1993, V.5, No.2, pp.16-24.
2. Bakhrakh S.M., Kovalev N.P. Taylor instability in elastic-plastic media// Chisl. Metody Mekh. Splosh. Sredy, Novosibirsk, 1980, V.11, No.2, pp.5-21.

Abstract number: 229

Shock Wave Stability in Two-Phase Liquid-Gas Region in Metals

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Abstract: Shock Hugoniots of metal with different initial volume and pressure have been calculated with the use of multi-phase equation of state. An application of D'yakov's criterion revealed an existence of specific sound instability of the shock wave in the liquid-gas region. The instability arises as a spontaneous sound emission from the shock discontinuity. The position of the instability region and its dependence on initial pressure and volume have been analyzed. The major effect responsible for the instability is a small value of sound velocity in liquid-gas mixture. Discussed are general regularities obtained on the base of the analysis for 30 metals. A possible experimental setup for investigation of the instability is proposed.

Abstract number: 230

Study of Rearrangement of Shock Wave Structure in Reacting Gases

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Abstract: It is a well known fact that a shock wave with exothermal flow behind it, is unstable [1]. It is of current interest to study a shocked gas with realized exothermal reactions. The examples of such flows are bow shock, multicomponent reacting gas behind the bow shock [2], instabilities occurring in plasmas [3]. This interest is mostly due to the possibility for decreasing drag because of eliminating the energy losses relative to the increase in entropy of a shock. The most reduction is observed for hypersound flows. Now we can understand the reasons of obtaining a reduced drag by one part of researchers while another did not reach this result.

As found the perturbation growth occurs at the stages of ionization and chemical dissociation. In the case of polyatomic gases the mean perturbation energy coincides with the chemical one [4]. This work deals with the longitudinal 2D flow of a compressible reacting gas. The influence of shear viscosity is assumed to be negligible in comparison with the internal, chemical processes.

The energy of chemical transfer is considered as the volume power of energy release - Q. Its derivations by temperature and gas density are taken into account. Geometry is accounted through the gradient of gas velocity across the layer - U'. The direction of coordinate across the layer is chosen along the direction of pressure disturbances spreading. The basic equations are reduced in a single differential equation of second order [5].

The computations for endothermal chemical processes (dissociation) with normal thermal and pressure dependencies show two complex and two real solutions. The case of more interest is $U' > 0$, because it corresponds to convex flow. In this case real solutions are stable, but "wave" solution at some parameters can be unstable.

Estimations for the flux of ionized air in a hypersonic intake near the throat pointed to flow rearrangement of throat shock flow at disturbances of ultrasonic frequency (> 8 kHz). This gives a possibility for controlling the flux using ultrasonic methods.

References

1. Zeldovich Ja.B., Barenblat G.I., Librovich V.B., Mahviladze G.I. (1980) Mathematical theory of combustion and explosion. Moscow, "Nauka"
2. Baryshnikov et al. 1996 Baryshnikov A.S., Basargin I.V., Dubinina E.V., Fedotov D.A. (1996) Rearrangement of shock wave structure in a decaying discharge plasma. Tech.Phys.Lett.23:259-260
3. Baryshnikov et al. 1979 Baryshnikov A.S., Bedin A.P., Maslennikov V.G., Mishin G.I. (1979) About instability of bow shock wave. Pis'ma v Zh.Tekh.Fiz. 5:281-284
4. Baryshnikov et al. 1983 Baryshnikov A.S., Bedin A.P., Derevjanko V.G., Rumjantsev A.A. (1983) Statistical characteristics of flow fluctuations and shock wave instability mechanism in relaxing gases. Paper, Physical-Technical Institute, N 816
5. Gaponov et al. 1980 Gaponov S.A. and Maslov A.A. (1980) Disturbances evolution in compressed flows. Novosibirsk, "Nauka"

Abstract number: 231

Direct Numerical Simulation of Magnetic Field Turbulent Diffusion in Accelerated Plasma

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Abstract: The problem of nonlinear evolution of random small-scale perturbations on accelerated boundary between ideal plasma and magnetic field is considered.
Physical model, numerical method and results of direct (two and three-dimensional) numerical modeling are presented.
The calculations were carried out with reference to experiments with one-cascade by explosive magnetic generators of a type "MK-1" with the program complex EGAK [1].
The results of calculations are compared with predictions of appropriate semi-empirical model [2] and experimental data [3].

References

1. Yanilkin Yu.V., Shanin A.A., Kovalev N.P. et al. VANT, Ser. MMFP, No.4, 1993. The program complex EGAK for calculations 2D flows of multicomponent media. VANT, ser. MMFP, v.4, 1993.
2. Gubkov E.V., Zhmailo V.A., Yanilkin Yu.V. Turbulent diffusion of magnetic field in accelerated plasme. The report on XXV Zvenigorod conference on physics of plasma and CTS, 1998.
3. Pavlovskiy A.I. et.al. DAN USSR, 1965, v.160, N1, p. 68.

Abstract number: 232

3D Numerical Simulation of Turbulent Mixing Using k-ε Turbulence Model

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Abstract: The presentation describes the technique TREK-T for computing 3D compressible medium flows taking into account turbulent mixing with semi-empirical turbulence model. The proposed model is an extension of the 2D k-ε model [1] which has been verified on a wide class of gas-dynamical problems to three dimensions. The model is implemented basing on an implicit version of the TREK Lagrangian-Eulerian gas-dynamical code [2] which allows to use it to simulate flows in a wide range of Mach numbers.

Numerical simulation results are presented for two 3D problems: the problem of explosion cloud rising in atmosphere and the problem of turbulent mixing evolution at the GEM-air interface at one-point GEM initiation [3]. The computed data is compared with computations using 2D techniques and with experimental data. A computed data processing method corresponding to experimental shadowgraphs is proposed. The computed and experimental shadow patterns are compared with each other. The agreement is satisfactory.

References

1. Yanilkin Yu.V., Nikiforov V.V., Bondarenko Yu.A., Gubkov E.V., Zharova G.V., Statsenko V.P., Tarasov V.I. Two-parameter model and method for computations of turbulent mixing in 2D compressible flows. 5th International Workshop on the Phisics of compressible turbulent mixing, Stony Brook (USA), 1995.
2. Gavrilova E.S., Dibirov O.A., Stadnik A.L., Tarasov V.I., Toropova T.A., Shanin A.A., Yanilkin Yu.V. Program system TREK for numerical simulation of 3D multi-component medium flows. Proc. of the 11th All-Russian Conference "Theoretic fundamentals and designing of numerical algorithms for solving computational physics problems", Pushchino, October 5-9, 1996, 24, 1996.
3. Stadnik A.L., Yanilkin Yu.V., Zhmailo, V.A. et al. The perturbations and Turbulent Mixing Evolution at the Plane Gas-Gas Interface in GEM-Driven Shock-Tube Experiments. 6thInternational Workshop on the Physics of compressible turbulent mixing, Marseilles, 1997.

Abstract number: 233

Development of an Instability During Motion of Metal-Insulator Phase Boundary

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Abstract: The diffusion of a magnetic field into a conductor, which undergoes a transition to a dielectric state under Joule heating, is considered. A subsonic motion of the phase boundary is investigated. Since usual magnetohydrodynamical instability practically do not develop during the motion of the phase boundary, an instability of a new type is dominated. Non-uniform heating of a conductor with a perturbated boundary appears. This, in turn, leads to a growth of the instability. The development of the instability in the linear stage is investigated as a function of the wave number. An influence of the instability of the phase boundary on performance of a fast electrical opening switch based on solid solution $(V_{1-X}Cr_X)_2O_3$ is estimated.

Abstract number: 234

Turbulent Combustion of Hydrogen-Air Mixture in a Closed Vessel

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Abstract: The presentation discusses numerical simulation of the problem from [1] which presents experimental and computed data of various authors pertaining to experiment [2] on combustion of depleted hydrogen-air mixture (7.5%) in a cylindrical vessel.

The computation was conducted with 2D technique EGAK-T [3] involving gas dynamics with the *k*-ε model [4] of turbulent mixing.

The intermediate composition of the combustion products was determined with kinetic equations for 9 components. The relevant equation of state was calculated with using thermodynamical functions [5].

The computational mesh was varied in the computations, in doing so the computed data were close to each other which allows to infer smallness of the scheme effects.

The computed time dependence of pressure satisfactorily agrees with the measured data of [2] as well as with the computed data presented therein.

The work is carried out under support of the ISTC, Project #436.

References

1. Tiselj I., A.Kodre, B.Mavko, "Two models of hydrogen combustion in a closed cylinder", in Proc. of a workshop held in Brussels (Belgium), march 1991, "Hydrogen behavior and mitigation in water-cooled nuclear power reactors", EUR 14039 en, 1992.
2. J.R.Travis,"Hydrogen transport, mixing and combustion studies", Los Alamos National Laboratory Report 87545, 1984.
3. Yanilkin Yu.V., Tarasov V.I., Zharova G.V., Eliseev G.M., Nikiforov V.V., Shemyakin V.Yu., Statsenko V.P., Chistyakov A.A. Adaptation of the EGAK program complex for numerical modeling of 2D flows with hydrogen combustion (the EGAK-FIRE code). ISTC Project N° 436, 1998.
4. Yanilkin Yu.V., Nikiforov V.V., Bondarenko Yu.A., Gubkov E.V., Zharova G.V., Statsenko V.P., Tarasov V.I. Two-parameter model and method for computations of turbulent mixing in 2D compressible flows. 5rd International Workshop on the Phisics of compressible turbulent mixing, Stony Brook (USA), 1995.
5. Gurvich L.V., Weitz I.V., Medvedev V.A. et al. Thermodynamical properties of individual materials, V.1, book 2, Moscow, Nauka Publishers, 1978.

Abstract number: 235

Some Features of Richtmyer-Meshkov Instability Evolution

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Abstract: Universal dependence, permitting to describe linear and non-linear stages of Richtmyer-Meshkov instability evolution was obtained earlier. A kind of this dependence for incident shock wave Mach number M=3.5 and Atwood number A=0.45 was determined on the basis of experimental data.
In the present paper it is shown with the use of direct numerical simulation by two-dimensional MAH code, that obtained dependence is correct for wide range of Atwood and Mach numbers.

Abstract number: 236

Instabilities Development of Rayleigh-Taylor Type in Fast Rotating Cylindrical Shells

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Abstract: The processes of instabilities development of Rayleigh-Taylor (R-T) type, appearing in the acceleration process of heavy cylindrical conducting rotating Al and Cu shells with ultra-high pulsed magnetic field on the separation boundary liquid shell–compressed light liquid or gas, or magnetic field, are simulated in the paper. The development processes of R-T disturbances, depending on the initial rotation velocity of the shell and different values of viscosity coefficients and yield point, are compared. Equation of motion is written in polar coordinates r,φ for random element of uncompressed shell in the presence of cylindrical symmetry considering viscosity, yield point and differential rotation.

Calculations are performed for a wide spectrum of initial angle velocities, amplitudes, wave lengths of the initial disturbances and shell dimensions. They showed, that fast rotation depresses the development of heavy liquid streams to the light one, decreases the total disturbance amplitude, but increases amplitude of the disturbance, directed from light liquid to heavy one and changes the disturbance shape from symmetrical to asymmetrical.

Abstract number: 237

Instability of Free Surface Solid. Analytical Studies

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Abstract: The emergence of a shock wave from a free surface in solids is followed by the increase in perturbation growth. This process fails to be limited in liquids and gases unlike the case of solids where strength can suppress the instability growth. The results of analytical solution for the stable free surface boundary in viscous and elastic-plastic material are reported. The effect of thermal softening and brittle break-up followed the perturbation growth are estimated.

Abstract number: 238

Study of R-T Instability in Solid at a Pressure of up to ~70 GPa

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Abstract: At a certain combination of loading characteristics and initial disturbances R-T instability evolution in solids turns out to be highly sensitive to the shear strength value. This effect served as the basis for developing the method of testing wide range strength models.
Evolution of disturbances on the loaded surface is experimentally measured using X-ray technique and streak-camera recording. Characteristics of loading, initial amplitude, temperature, strain rate, etc., are varied.

The possibility of varying physical parameters over wide limits (T, P, $\dot{\varepsilon}$) allows effects of these parameteres produced upon the shear strength to be studied. Resently the range of pressures coming up to 70 GPa and strain rates of $\sim 10^3$-10^6 s^{-1} have been investigated using explosive loading devices.
The paper presents the most typical experimental setups and some results. The method perspectives have been evaluated.

Abstract number: 239

Instability of Accelerated Perfect-Viscous Fluids Interface at Simultaneous Action of Constant and Pulsed Accelerations

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Abstract: Mathematical problems arising when studying instability of accelerated media boundaries are complicated and diversiform. Paper [1] studies perturbation evolution of the elastic body-fluid interface under separate action of both constant and pulsed accelerations. A similar study for viscous media is conducted in papers [2,3]. Solutions to problems of simultaneous action of constant and pulsed accelerations for two incompressible fluids and for the fluid-elastic body interface can be found in papers [4,5]. This paper analytically and numerically solves the problem of Rayleigh-Taylor instability for the perfect fluid – viscous fluid interface at a simultaneous action of constant and pulsed accelerations.

A complex research into the problem under study has been conducted to describe the perfect-viscous fluids interface evolution under simultaneous action of constant and pulsed acceleration.

In the linear approximation an analytical solution to the problem is obtained.

Applicability of the method for approximate description of real gas-dynamical flows is shown (by the example of shock tube test computation).

The analytical solution obtained in the paper agrees with the numerical computations and the experiment.

The obtained results can be used as benchmarking at development and validation of techniques as well as are of a certain practical value at assessment of perturbation evolution in complex systems.

References

1. Bakhrakh S.M., Kovalev N.P. Taylor instability in elastic-plastic media// Chisl. Metody Mekh. Splosh. Sredy, Novosibirsk, 1980, V.11, No.2, pp.5-21.
2. Anuchina N.N., Bakhrakh S.M., Zabrodin A.V., Pliner L.A., Sofronov I.D. Studies on hydrodynamic instability of two media interface// Computer study of hydrodynamic instability/ Ed.by K.I.Babenko. Moscow, USSR Academy of Sciences KIAI, 1981.
3. Bellman R., Pennington P. Effects of surface tension and viscosity on Taylor instability// Quart. J. Appl. Math., 1954, p.151-162.
4. Neuvazhayev V.E., Parshukov I.E. Studying instability of fluid interfaces under simultaneous action of pulsed and constant accelerations// Mat. Modelirovaniye, 1993, V.5, No.2, pp.16-24.
5. Bakhrakh S.M., Kornilov Yu.I. Elastic body interface perturbation evolution under simultaneous action of constant and pulsed accelerations// VANT. Ser. Mat. Modelir. Fiz. Protsessov. 1998, No.3.

Abstract number: 240

Instability of an Accelerated Thin Elastic Layer

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Abstract: Analytical solutions are found for evolution of 2D and 3D initial perturbations of an accelerated elastic thin layer. Expressions are obtained for the perturbation increment and critical acceleration. It is shown that, in contrast to fluid, 3D elastic layer perturbations (at quite a high shear modulus) grow not faster than 2D ones do.
The obtained analytical solutions are in a good agreement with 2D and 3D computations with the full system of the laws of conservation of compressible continuum.
This effort is a natural continuation of the studies presented at the 6th International Workshop on the Physics of Compressible Turbulent Mixing [1,2].

References

1. Bakhrakh S.M., G.P.Simonov G.P. Analytical and Numerical Studies of the Rayleigh-Taylor Instability of a Thin Liquid Layer// Proc. of the 6th International Workshop on the Physics of Compressible Turbulent Mixing, France, Marseille, 18-21 June, 1997, pp.50-56.
2. Bakhrakh S.M., G.P.Simonov G.P. Rayleigh-Taylor Instability of a Thin Liquid Layer Provided 3D Perturbations// Proc. of the 6th International Workshop on the Physics of Compressible Turbulent Mixing, France, Marseille, 18-21 June, 1997, pp.57-63.

Abstract number: 241

Prediction of Mixing Zone Growth in Terms of Successive Averaging over Multimode Spectrum of Initial Perturbations

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Abstract: The R-T instability, which is followed by mixing layer occurrence, was studied for the 2D case from the point of fundamental processes in the development of hydrodynamic instabilities and turbulent mixing [1]. A complex, multimode perturbation was chosen as initial condition. For the initial complex spectrum to be divided into components of different scales we employed a method of averaging which was described in [2]. The calculations were performed using NUT codes [3]. The separate analysis for the components different in scale shows the nonlinear stage can be described "additively". The results obtained allow various parameters of nonlinear and turbulent stage such as turbulent mixing width, penetrated mass, etc., to be predicted in terms of initial complex spectra.

References:

1. N.V.Zmitrenko, N.G.Proncheva, V.B.Rozanov. Evolution model for turbulent mixing layer // FIAN Preprint, N65, 1997.
2. V.B.Rozanov, R.V.Stepanov. Analysis of complex, multimode perturbation spectra on interface for the problem of hydrodynamic instabilities. // FIAN Preprint, N70, 1997.
3. V.F.Tishkin, V.V.Nikishin, I.V.Popov, A.P.Favorsky. Difference schemes of 3D gasdynamics for the problem of Richtmyer – Meshkov instability growth. // Mathematical modeling, 1995, v.7, N5, p.15-25

Abstract number: 242

3D Numerical Simulation of Rayleigh-Taylor Instability Using MAH-3 Code

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Abstract: Interface between two fluids of different densities is unstable and behaves as Rayleigh-Taylor instability if it is affected by acceleration directed from light fluid to the heavy one. A square law was proposed in [1] to describe extension of a turbulent mixing zone after achieving self-similar phase.

Usually sufficient conditions for treating a flow as selfsimilar turbulent, is realization of the square law for mixing zone extension and spatial-temporal similarity of the averaged density profiles within some time interval. However, to qualify turbulent mixing as self-similar it is necessary to consider the internal features of the flow based on spectral presentation of hydrodynamic fields. This means that in addition to determining spatial-temporal similarity of flow functionals it is necessary to verify whether there exists an inertial interval of wave numbers within which the Kolmogorov-Obukhov "five thirds" law [2] of turbulent kinetic energy power spectrum is valid.

Turbulence energy spectrum distribution was used, for instance, in Refs. [3-5] to analyze the results of numerical simulation of gravity turbulent mixing.

A criterion of determining self-similar turbulent phase of flow can be stated:

*presence of self-similar inertial mechanism of transferring energy of velocity field pulsation at the intermediate range of wave numbers;

*spatial-temporal similarity of a representative enough set of flow functionals.

The results are presented obtained in 3D numerical study of turbulent phase of Rayleigh-Taylor instability evolution using MAH 3 code.

Analysis of dynamics of turbulent specific kinetic energy power spectrum has shown that there are three phases of turbulent mixing: "relict chaos", "classical energy spectrum" and "spectrum degradation".

In calculations energy and dissipation ranges can overlap significantly due to a small number of points and excessive dissipation of the difference scheme. This leads to an absent phase of formation and existence of the classical spectrum of turbulent kinetic energy. Without energy spectrum control, determination of integral functionals might give information irrelevant to self-similar turbulence.

The work was performed under ISTC Project №177.

References

1. N.N. Anuchina, Yu.A. Kucherenko, V.E. Neuvazhaev, et al. Turbulent Mixing at the Accelerating Interface between Fluids with Different Densities. Fluid and Gas Mechanics, #6, 1978.
2. A.M. Obukhov. On Energy Distribution in Turbulent Flow Spectrum. Reports of the USSR Academy of Science, v.32, #1, 1941.
3. S.B. Dalziel, P.F. Linden, D.L. Youngs. Self-similarity and internal structure of turbulence induced by Rayleigh-Taylor instability. Proceedings of the sixth international workshop on the physics of compressible turbulent mixing, Marseille 18-21 June 1997, France.
4. O.G. Sin'kova, A.L. Stadnik, V.P. Statsenko, Y.V. Yanilkin, V.A. Zhmailo. Three-dimensional numerical simulation of gravitational turbulent mixing. Proceedings of the sixth international workshop on the physics of compressible turbulent mixing, Marseille 18-21 June 1997, France.
5. N.N. Anuchina, N.S. Es'kov, A.V. Polionov, O.S. Ilyutina, O.M. Kozyrev, V.I. Volkov. Numerical analysis of nonlinear RayleighTaylor instability. Proceedings of the sixth international workshop on the physics of compressible turbulent mixing, Marseille 18-21 June 1997, France.

Abstract number: 243

Method of Numerical Simulation of Contact Surface with Strong Distortions

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Abstract: The paper describes a method of numerical simulation of contact surfaces with strong distortions which is implemented in a complex of codes MAH [1-2].
Complex of codes MAH is intended to calculate nonstationary 2D problems of gas dynamics.
A system to be calculated is presented as a set of computational regions based on a priori information about the processes in the system.
Given specifics of processes under consideration, different simulation methods can be applied in the course of problem calculation to compute different regions or the same region but at various phases of simulation. If there are no vortex flows, calculation can be done in Lagrangian variables. If there is significant transfer of matter, vortex flows, strong distortions, Eulerian variables are used with regular or irregular description of contact discontinuities within the region.
In the regular method, contact surface is a coordinate Lagrangian line of the mesh.
The irregular method is used to calculate strong distortions of interfaces between substances. In this method particles-markers that are located on the interface between substances are used to describe contact discontinuity. Markers, which coordinates are calculated at each step, identify position of the contact surface.
Some method capabilities to calculate vortex flows and processes with strongly distorted contact surfaces are illustrated in the problems of hydrodynamic instability. The examples are connected to researches of hydrodynamic instability, carried out within the framework of the project ISTC #177.

References

1. Hirt, C.W., Amsden, A.A. Cook, J.L. An arbitrary lagrangian- eulerian computing method for all flow speed. J. of Comput. Physics 14, 3, 1974.
2. Anuchina, N.N., Volkov, V.I., Es'kov, N.S. Numerical Modeling of Multi-Dimensional Flows with Large Deformations. Report at Russian/U.S. Weapons Laboratories introductory technical exchange in computational and computer science. Livermore, 1992.

Abstract number: 245

Effect of Chemical He Explosion Product Turbulent Afterburning on Gas-Dynamical Processes in Closed Chambers

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Abstract: When designing explosive chambers, of a high importance is a thorough study int pulsed loads on chamber walls. Here the strain level is influenced not only by the first pressur pulse arriving at the chamber walls, but also by the amplitude and arrival time of the followin pressure pulses after wave convergence and reflection at the spherical chamber center.
Derivation of a chamber wall pulsed pressure dependence through solution of the ordinary gas dynamical problem is not accurate for two reasons. First, it is necessary to take int consideration that the spherical interface between expanding explosion products (EP) an surrounding air becomes unstable with respect to small perturbations and at a repeated passag of the shock wave from the chamber walls to the center and back turbulent mixing of EP wit atmospheric air filling the chamber proceeds at the interface. The second reason relates to th fact that HE of a negative oxygen balance are usually used at whose detonation in E incompletely oxidized components in the form of free carbon, hydrogen, carbon oxide ar present. Mixing of these highly heated EP with chamber air results in their after-oxidation wit air oxygen (after-burning) with additional energy release. As experiments indicate, the additiona energy release can be higher than that at detonation.
The paper discusses results of experimental studies of the processes and those of numerica computations to determine the dependence of the pressure on the chamber wall with allowanc for the turbulent mixing and the after-burning.

Abstract number: 246

Experimental & Calculation Investigation into Peculiarities of the Gravitational Turbulent Mixing at the Inclined Contact Boundary

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Abstract: It has been studied the size growth of the different density liquids mixed region with a contact boundary initially inclined to the acceleration vector. For the initial angles of inclination $\theta_0 = 5^0 46'$, 10^0, 15^0, 30^0, 45^0 and 60^0 the experiments at the installation SOM and direct numeral modeling with using MAX-code have been performed. The density ratio for liquids amounted to $n = 3$, the ampoule acceleration was equal 730 g, g is the Earth's gravity acceleration. It had been observed in both experiments and calculation that, in the process of ampoule acceleration, the mixed region had a rotation with the more angle velocity the higher its initial incline was. In all the experiments it had been found out that the growth of the mixed region was stopping in the course of time. At the same time the width of the mixed region has reached some maximum at the instant of time when the mixed region has rotated by the same angle $\theta_{\bar{n}} = 36,4^0$. Further the width of the mixed region was decreased. Numerical results are compared with experimental ones and possible reasons for stabilizing the mixed region evolution are discussed.

Abstract number: 247

Experimental Investigation of the Rayleigh-Taylor Turbulent Mixing Zone Evolution Following Negative Acceleration Pulse Acting

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Abstract: Experimental study of the impulse acceleration influence on the turbulized layer behavior had been performed. The turbulized layer arisen in result of Rayleigh-Taylor instability acting to the system of two different density liquids with the density ratio n =3. After acting of impulse acceleration, the system was moving according to inertia and the coordinates of penetration of the heavier liquid into the lighter one and vice versa had been taken with using the light method. The liquids studied were placed inside the ampoule that had internal working sizes 54 x 64 x 120 mm. There were initial accidental perturbations like a rough solid surface at the interface and the width of the initial perturbation zone was L_0 = 2.3 mm. A moving ampoule blow to metal plates created the impulse acceleration. The relative impulse acceleration was $\delta g/g_{11}$ = 22.2 – 66.6 where g_{11} is the ampoule acceleration before the blow, the impulse duration was from 0.27 ms to 0.096 ms. The results concerning the turbulized layer extension after impulse acceleration acting had been obtained.

Abstract number: 248

Experimental Study into the Periodical Perturbations Evolution against a Turbulent Mixing Background in the Contact Boundary Region of Different Density Liquids

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Abstract: By applying the X-ray diffraction technique at the installation EKAP the experimental investigation of the periodical perturbations evolution against a background of turbulent mixing in the region of the contact boundary between different density liquids with the density ratio n=2 has been performed.

Dependence of the growth of the periodical perturbation amplitude at the different wavelength on the contact boundary displacement has been determined. The results of the direct numerical modeling by the program complex MAX have been given. The comparison of the growth rate of the perturbation amplitude with and without taking into account the turbulent mixing is made.

Abstract number: 249

Experimental Investigation of Turbulent Mixing in Three-Layered Systems

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Abstract: At the installation EKAP the experimental investigation of the gravitational turbulent mixing in three-layered systems with two unstable contact boundaries has been performed. On the first and second contact boundaries the density ratio amounted to $n_{1.3} = n_{3.2} = 4.4$.
Dependence of the mixing front coordinate in the light liquid on the contact boundary displacement has been determined. It is noted that the finite thickness layers placed between the heavy liquid and light one and possessed of the intermediate density, which is constant in the layer thickness, make possible to organize the delay in the gravitational turbulent mixing evolution.

Abstract number: 250

Investigation of the Stationary Shock Wave Dispersion at the Turbulent Layer Passage

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Abstract: In Russian Federal Nuclear Center – VNIITF the experiment at the installation OSA with respect to studying the stationary shock wave dispersion after the turbulized layer passage has been performed.

In the calculations of the targets compression, in the laser thermonuclear fusion problem, the results of experiments will be used. At the contact boundary of two different density gases, at the external initiation of the controlled separating membrane prior to the stationary shock wave arrival, the turbulized layer was formed.

At the modernized installation OSA several groups of experiments regarding the interaction of the stationary shock wave with the turbulized layer have been performed. In experiments Atwood number assumed the values A=0.54 and A=0.82. A new method for obtaining the turbulized layer made possible to carry out experiments with Atwood number A=0. The stationary shock waves with Mach number M=1.7 and M=2.0 were generated. In the experiments the initial thickness of the turbulized layer was varied. The dependence of the stationary shock wave dispersion after the turbulized layer passage has been experimentally determined.

Abstract number: 251

Investigation of the Instability Evolution on the Contact Boundary of Different Density Liquids at Pulse Acceleration

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Abstract: Experimental investigation of the instability evolution on the contact boundary of two different density liquids with density ratio n=3 and n=6 at the impulse acceleration has been performed.
The dependencies of the growth rate of the perturbations amplitude in the light liquid on the contact boundary displacement and the results of the direct numerical modeling by the program complex MAX have been given. The comparison of the experimental and numerical results is carried.

Abstract number: 252

Study of Influence of Eccentricity of Converging Shock Wave on Compression of Light Gas by Heavy Gas in the Cylindrical Case

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Abstract: The paper describes experimental study of perturbations growth at the contact boundary between light (internal area) and heavy (external area) gases accelerated by converging shock wave in the cylindrical case. The initial perturbation was specified as displacement (eccentricity) of the light gas area regarding to the converging wave. The converging wave was caused by electric explosion of wires located at the internal surface of semicylinder made of organic glass. Areas with different gases were separated by thin organic films. The flow picture was visualized by the shadow method and was recorded by streak camera in the time magnifier variant.

Experiments show that boundary perturbation growth results in formation of heavy gas jet penetrating into light gas in the place where wave arrives at the boundary with outstripping. In the process of compression the scale of this perturbation grows. At the time of the maximum compression its amplitude becomes comparative to sizes of light gas. With eccentricity growth the perturbation occurs earlier and reaches greater sizes. The perturbation growth is followed by growth of small-scale perturbations and turbulent mixing at the boundary. Strong distortion of boundary of light gas area results in mixing of heavy gas into light gas quicker in comparison with the symmetrical case. At eccentricity increase the reached compression of light gas is slightly reduced.

Abstract number: 253

On Possibility of Modeling Some Characteristics of R-T Instability Growth in Solids

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Abstract: Since 1979, VNIIEF has employed jelly method for studying R-T instability growth on the interface between gas and liquid as well as gas and solid.
The method is based on using a model of "heavy" layer being a jelly of water – solved gelatin with concentration C, and driven by a compressed gas. The change in C (from 3 to 50%) allows one to obtain layers which being driven behave like liquid ($C \approx 4\%$) or material with strength ($C > 5\%$).
The strength properties of jellies are of particular interest while they are used for modeling R-T instability growth in solids. For jelly strength to be determined we tested statically water – solved gelatin under compression. Having different gelatin concentration C and being of diameter d=20 mm and d=30 mm, the samples were tested under loading rate of V=1mm/min and V=10 mm/min, at T=16.5÷25°C. As a result, we recorded jelly strength as a function of various parameters such as concentration, temperature.
The performed experiments on growth of periodical longitudinal perturbations (sinusoid with perturbation amplitude a_0 of 1.5 mm and wavelength λ=15 mm) and comparison with production in terms of elastic semi–space (such system configuration allows one to use such analytical solution) state that the jelly technique application includes modeling some characteristics of R-T instability in solids as well as that on its upgrading, this technique.

Abstract number: 254

Principle of Birkhoff Maximum and Asymptotic Dynamics of RT and RM Bubble Fronts

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Abstract: The mean perturbation wavelength approximation (see, e.g., [1]) for description of Rayleigh-Taylor (RT) and Richtmyer-Meshkov (RM) instability bubble front evolution is discussed. A feature in which the proposed approach differs from [1] is using the principle of maximum rate of potential energy conversion to kinetic energy of perturbations proposed by G. Birkhoff [2] in the Rayleigh-Taylor instability problems. This allowed to relate in a closed manner the evolution dynamics of a separate bubble within simple model [3] and the asymptotic dynamics of RT and RM bubble fronts in self-similar conditions. It is found that for the RT bubble front h (at Atwood number A=1)

$h \sim \alpha g t^2$,

where g is acceleration, t is time, α is a constant being α=0.06 (for 2D bubbles), α=0.08-0.10 (for 3D bubbles).

For the RM bubble front (at A=1) it is found within the proposed approach that $h \sim t^{\theta}$ where θ=0.47.

References

1. U.Alon, J.Hecht, D.Mukamel, D.Shvarts, Phys.Rev.Lett, v.72, p.2867,(1994).
2. G.Birkhoff, Los Alamos report LA-1927 (1956).
3. M.D.Kamchibekov, PMTF, No. 6,1985.

Abstract number: 255

Numerical Simulation of Gravitational Turbulent Mixing of a Light Plane Layer with Surrounding Fluid

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Abstract: The 3D direct numerical simulation of turbulent mixing on a plane interface of two different density incompressible liquids (gases) moving at a constant acceleration was previously made in [1,2].

This paper uses a similar approach for solution of the problem of turbulent mixing in the field of gravity of a light plane layer located in infinite homogeneous fluid. Like in [2], programs TREK [3] are used for the simulation.

Spectral study of velocity and density pulsations in the mixing zone was conducted: approximation to the Kholmogorov spectrum in 3D computation was studied.

The theoretical and computational study was also conducted in 1D formulation with numerical technique EGAK-T [4] which uses semi-empirical k-ε model of turbulence [5] to simulate the turbulent mixing.

The 1D and 3D computations are compared both with each other and with similar data computed in [6] as well as with experimental data.

References

1. Youngs D.L., Numerical simulation of mixing by Rayleigh-Taylor and Richtmyer-Meshkov instabilites, Laser and Particle Beams (1994), vol 12, No. 4, pp. 725-750.
2. Zhmailo V.A., Stadnik A.L., Statsenko V.P., Yanilkin Yu.V. Direct numerical simulation of gravitational turbulent mixing, VANT, Ser. Teor. i Prikl. Fizika, No.2, 1995.
3. Stadnik A.L., Shanin A.A., Yanilkin Yu.V. Eulerian technique TREK for computing 3D gas-dynamical multi-component fluid flows. VANT, Ser. Mat. Modelir. Fiz. Protsessov, No.4, pp.71-78, 1994.
4. Yanilkin Yu.V., Nikiforov V.V., Zharova G.V. A model with two equations and a technique for computing turbulent mixing in 2D compressible flows. VANT, Ser. Mat. Modelir. Fiz. Protsessov, No.4, 1994.
5. Statsenko V.P., Velichko O.M., Yanilkin Yu.V., Zharova G.V. Buoyant plume generation. Presentation at this Conference.
6. Zherebtsov V.A., Zhmailo V.A., Statsenko V.P. Self-similar solutions to semi-empirical equations of turbulent mixing in 1D unsteady flows.// Chisl. Met. Mekh. Splosh. Sredy, V.15, No.1, Novosibirsk, 1983, pp.60-75.

Abstract number: 256

Numerical Simulation of Turbulent Mixing at Spherically Symmetric Gem Explosion in Surrounding Gas

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Abstract: The paper discusses results of numerical (1D and 3D) simulation for evolution of a turbulent mixing zone (TMZ) arising inside a spherical vessel at an interface of two gases at passage of several spherical shock waves (SW) from explosion of gaseous explosive mixture (GEM). One of the gases in the experiments was GEM explosion products, the other was represented with various incombustible ("inert") gases: air, xenon (Xe), freon-12, neon.
The purpose of the experiments suggested in this setting-up [1] is measuring parameters of the turbulence: conditions of its appearance change at replacement of the "inert" gases. A method to study the above parameters is obtaining and subsequent study of the interference pattern.
The theoretical and computational study for some "inert" gases was conducted in 1D formulation, like in [2], with 2D numerical technique EGAK-T [3] which uses the semi-empirical k-ε model of turbulence to simulate the turbulent mixing.
Thus obtained gas-dynamical profiles were used as a basis to compute the interference pattern; the latter shows that the band shear is in the range accessible to experimental processing.
In addition, direct numerical simulation of turbulence was also conducted with 3D gas-dynamical technique TREK [4] for a problem with air as the "inert" gas. The data from 3D computation on the whole is close to that from relevant 1D computation with phenomenological description of turbulence.

References

1. Meshkov E.E. A feasibility of experimental study of hydrodynamic instabilities. A dynamic method for making interfaces in gases. VNIIEF Preprint, 144-96, 1996.
2. Dudin V.I., Gubkov E.E., Meshkow E.E., Nikulin A.A., Stadnik A.L., Ststsenko V.P., Tilkunov V.A., Vlasov Y.A., Bashurov V.V., Bykova E.A., Tarasov V.I., Yanilkin Y.V., Zhmailo V.A., The perturbations and turbulent mixing evolution at the plane gas-gas interface in GEM-driven shock-tube experiments, Proc. of the 6th Int. Worksshop on the Physics of compressible turbulent mixing, Marseille, 1997, France, pp.152-160.
3. Yanilkin Yu.V., Nikiforov V.V., Zharova G.V. A model with two equations and a technique for computing turbulent mixing in 2D compressible flows. VANT, Ser. Mat. Modelir. Fiz. Protsessov, No.4, 1994.
4. Stadnik A.L., Shanin A.A., Yanilkin Yu.V. Eulerian technique TREK for computing 3D gas-dynamical multi-component fluid flows. VANT, Ser. Mat. Modelir. Fiz. Protsessov, No.4, pp.71-78, 1994.

Abstract number: 257

Buoyant Plume Generation

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Abstract: The experiment discussed in [1] studied an axisymmetric buoyant plume generated at vertical release of heated air to the atmosphere from a reservoir.

In [2] we carried out numerical simulation of the above experiment with 2D gas-dynamical technique of programs EGAK [3] with using semi-empirical k-ε model of turbulent mixing. The model was obtained in [2] from a version of semi-empirical theory [4] by making minor modifications to the equation of motion and to the equation for turbulent energy k written in model [4] in their simplified form. Although the computed data pertaining to the density profiles and pulsations was quite close to measurements, the velocity and turbulent energy profiles were described unsatisfactorily in [2].

In this paper we use the k-ε turbulence model obtained from a Reynolds equation set in a more consistent manner. This leads to somewhat another equation form and, which is most important, to another system of phenomenological factors responsible for the "gravitational" mixing.

The data from 2D numerical computations proves considerably closer to that found in [1], than that of [2].

The work is carried out under support of the ISTC, Project #436.

References

1. William K.George.Jr., Ronald L.Alpert and Francesko Tamanini. Turbulence measurements in an axisymmetric buoyant plume, Int.J. Heat Mass Transfer, vol.20, pp.1145-1154, 1977.
2. Statsenko V.P., Yanilkin Yu.V., Zharova G.V., F.Jeffry Martin, Kin Lam. Buoyant plume generation. VANT, Ser. Teor. i Prikl. Fiz., No.3/1, 1994/1995.
3. Yanilkin Yu.V., Shanin A.A., Kovalev N.P. et al. Program system EGAK for computing 2D multi-component medium flows. VANT, Ser. Mat. Modelir. Fiz. Protsessov, 1993, No.4, pp.69-75.
4. Yanilkin Yu.V., Nikiforov V.V., Zharova G.V. A model with two equations and a technique for computing turbulent mixing in 2D compressible flows. VANT, Ser. Mat. Modelir. Fiz. Protsessov, 1995.

Abstract number: 259

Blast Wave Stability in a Non-Ideal Gas

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Abstract: Problem of stability of a selfsimilar blast wave in a non-ideal gas is considered. Small non-radial blast wave perturbations are expanded to spherical harmonics components of expansion being represented in a self-similar form. (The perturbation front amplitudes are supposed to be power functions of time with power exponent being complex number). The spherical and cylindrical blast waves are considered in the unified manner.
The adiabatic exponent of the non-ideal gas is supposed to be function of gas density. The blast wave in this gas is selfsimilar just like that is in the case of the ideal gas. So the selfsimilar approach to blast wave stability problem is used that was previously used in the case of blast wave in ideal gas [1-3].
We consider gas adiabatic exponent to be a simple one-parameter analytical function of density the value of parameter defining the level of gas non-ideality: from ideal gas to non-compressing liquid. For each level of non-ideality the stability problem is solved both for spherical and cylindrical blast waves.
The instability region is determined in the space of parameters of the problem: harmonic number and parameters of gas equation of state. The crytical values of parameters of equation of state are calculated.
The results are calculated numerically in the general case of arbitrary gas adiabatic exponent $\gamma(\rho)$ and harmonic number n and analytically in some special cases: n=1, n>>1, and γ - 1<< 1.

References

1. V.Ktitorov, Voprosy Atomnoi Nauki i Tekhniki (Atomic science and techn. issues), Ser.TPF,No2,p.28,(1984);
2. D.Ryu and E.T.Vishniac, Astr.J, 313, p.820 (1987);
3. V.Ktitorov, Khimich. Fizika (Chem Phys Issues) V.14, No 2-3, p.169, (1995);

Abstract number: 260

Study of Point Blast Wave Instability in Numerical Experiment

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Abstract: The detection of cases demonstrating an unstable evolution of the point blast wave in perfect gas was the problem actually formulated since 1980s when it was found with the help of self-similar approach to stability problem that for cases of gas specific ratio gamma being less than 1.20 blast wave became unstable: the Rayleigh-Taylor type instability showed up at the shock front [1-3].

Later these results were confirmed in computer experiments when 2D hydrodynamic code was used. This code selected shock wave front and used the 1-st order Godunov scheme.

In this paper we set ourselves the task of doing that using 3D hydrodynamic code. So we carry out computer simulation of blast wave using 3D Eulerian code TREK [4,5]. The other objective of computation is to determine if the regime of perturbation evolution depends on the second (angular) number of spherical harmonic.

The computation geometry is as follows:

At t=0, the initial pressure is set constant in the center region, and the pressure is equal to zero beyond this region. The central region presents a slightly perturbed sphere: the value of sphere radius has a small perturbation proportional to spherical harmonic (Legendre polynomial). The entire material is ideal gas with density being equal of unit and γ = 1.1- 1.2. The perturbations considered are of reasonably high harmonic polar numbers n: n=16 and higher.

Computation results are as follows:

We prove the perturbation amplitude increase in case of n=16 and γ <1.2 i.e. we get the direct proof of blast wave instability in these cases.

We prove also that the perturbations evolution mode converts to the self-similar pattern in a short time (i.e. when the shock front radius increased by 3-4 times) independently from initial conditions and further proceeds according to the self-similar theory.

We prove that oscillations period of non-axially symmetric harmonics is equal to that of axially symmetric ones with the same polar number n. We prove also that these periods are equal to that in self-similar theory [1-3].

The non linear stage of evolution of blast wave axially symmetric perturbations is also studied. The computation of raising perturbations evolution is continued until the formation of singularities and jets on the axis of symmetry and their turbulizations.

References

1. V.Ktitorov, Voprosy Atomnoi Nauki i Tekhniki, Ser.TPF, No2, p.28, (1984);
2. D.Ryu and E.T.Vishniac, Astr.J, 313, p.820 (1987);
3. V.Ktitorov, Khimich. Fizika (Chem Phys Issues) V.14, No 2-3, p. 169, (1995);
4. A.Stadnik, V.Tarasov, Yu. Yanilkin, Voprosy Atomnoi Nauki i Tekhniki, Ser.MMFP, No3,p.52,(1995);
5. Yu.Yanilkin et al., Proceedings of the 6th IWPTM, p. 520-526.

Abstract number: 261

Spectral Model for Description of RT Bubble Front Dynamics

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Abstract: Equations are obtained for amplitudes of N harmonics describing bubble front dynamics for the Rayleigh-Taylor (RT) instability (with Atwood number A=1) in incompressible inviscid fluid. The nonlinear interaction of the modes is accounted with consideration of the Cauchy-Lagrange integral in the asymtotic region (before the bubble front).

In the approximation N=20 the problem with the initial number of the harmonics n=ll and wave numbers k=10,11,...,20 and small initial amplitudes was numerically solved. Three characteristic conditions were found in the RT bubble front dynamics:

- exponential growth with dominant perturbation wavelength;
- quadratic law of front amplitude growth;
- transition to the linear growth of the front amplitude at a constant rate.

Comparison with the spectral Haan model is made and some possibilities to extend the proposed spectral model are considered.

Abstract number: 263

Instability Growth of Magnetically Imploded Cylindrical Liners Made of Aluminum and High-Strength Aluminum Alloys. Principal Results of the First Joint Pegasus-2 Experiments

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Abstract: The experimental data is presented on the growth of given initial perturbations of liners made of high-purity soft aluminum (A995, 99.995% Al), commercial-purity aluminum (ADO, 99% Al), and high-strength aluminum alloys with magnesium (AMg6) or zinc (B95) additives. Results of provisional study of the data are presented and compared with VNIIEF and LANL numerical simulation results which allow to assess parameters of dynamic strength and conductivity of materials used for designing magnetically driven liners from a new viewpoint.

Abstract number: 264

Study of the Near-Wall Effects Influence on Longitudinal Symmetry of a Condensed Liner Compressed by EMG Slowly Increasing Current

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Abstract: High longitudinal symmetry of cylindrical condensed liners in the process of their compression is necessary for effective magnetohydrodynamic compression. The violation of such symmetry may occur because of the interaction of the liners with the edge walls conducting current. Good longitudinal symmetry of the liners' motion can be observed at a relatively short current risetime, for example in the PEGASUS-2 facility experiments; however, it can be much worse in the experiments with a longer current risetime. This paper presents the results of the experimental and calculation-theoretical study of the near-wall effects' negative influence on the longitudinal symmetry of the cylindrical liners compression. These liners are as much as possible close in design to the experiments on PEGASUS-2 facility, but the duration of the helical EMG formed current' risetime is an order higher. In LT-1 experiment by means of radiography and contact probes there have been researched the liner motion at two angles of the edge walls inclination, with and without a notch on the cylindrical part of the edge wall under the liner in the place of its fastening. The experimental data are in good agreement with the results of computational modeling.

Abstract number: 265

Small Perturbation Method and Its Application to Studying Gas-Dynamical Instabilities

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Abstract: Study of relatively small perturbation stability uses the method of small parameter and Lagrangian approach to flow description. Items subjected to perturbations are initial boundary conditions Π of the problem describing the process under study which are additionally multiplied by the smallness parameter. The vector of particle deviation from the particle unperturbed trajectory is represented as Taylor series in variation of Π.

Equations (in the vector form) are presented for estimation of the first and second perturbation variations. Dimension of the flow under study and of perturbations can be any.

The numerical technique SP is designed for computing symmetric 1D flows with (or without) taking into account electronic heat conduction and the first variation of perturbations. Solution singularities and their numerical implementation as well as results of numerical study of shock wave, two media interface stability, effect of heat conduction, etc. are discussed. SP computations agree well with computations using 2D and 3D techniques at the initial instability evolution phase.

Computations by sum of two variations (new developments) expand the range of applicability of the small perturbation method.

The role of the second variation is demonstrated by the example of R-T instability evolution (analytical solution).

Abstract number: 266

On Feasibility of Rayleigh-Taylor Instability Magnetic Stabilization of Liner Implosion

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Abstract: The problem of small perturbation growth due to Rayleigh-Taylor instability has been theoretically considered when the liner implosion occurs under action of combined azimuthal and poloidal magnetic fields. It is shown that if the total magnetic field changes direction during the implosion, the magnetic stabilization of the perturbation growth takes place at any directions of the perturbation wave vector, in contrast to the case of liner acceleration by a magnetic field of a fixed direction when the magnetic stabilization does not work for perturbations' with a wave vector perpendicular to the magnetic field. The calculations for Pegasus-II liner experiments (LANL) showed that use of a poloidal magnetic field in combination with the azimuthal results in a considerable reduction in the perturbation growth.

Abstract number: 267

2D Instability Simulation of Magnetically Driven Cylindrical Aluminum and Aluminum Alloy Liners

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Abstract: Evolution of the Raleigh-Taylor (RT) type instability of magnetically driven metal liners depends on their strength (S) and Joule heating (J).
Two 2D numerical codes, MIMOZA and DRAKON-R/2, are used to simulate this (SJ-RT) instability. Conductivity is described for three materials differing in the quasi-static yield strength by a factor of 10-40: high-purity aluminum A995, "medium-strength" alloy AMg6, "super-strength" allow B95, The elastic-plastic medium approximation with strain and pressure dependence of dynamic strengthening and the elastic-plastic model are used.
Basing on a comparison of computed data for the first VNIIEF-LANL joint Pegasus-2 experiments with the experimental data the conclusion is made that the three above-mentioned materials showed about identical maximum dynamic yield strength of ~2 kbar.

Abstract number: 268

Experimental Research of the Disturbances and Turbulent Mixing Development on the Gases Stable Interface under the Action of Shock Wave Front

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Abstract: The measurements results of the disturbances sizes and zones of gases turbulent mixing are presented, observed due to the action of the intense deccelerating shock wave with M=3.3 on the interface of different density gases. The development of the disturbances and turbulent mixing took place as a consequence of Richtmyer-Meshkov instability because of shock wave front action, while in the field of action of pressure relief wave the interface was in a stable state.

The measurements were performed using schlieren-photography. Thin nitrocellulose membranes were used in the experiments for the preliminary gases separation. These membranes were exposed to the fast thermal decomposition under the high temperature behind the shock wave front (in less than 0.5 μs)

It is determined that for the initial disturbances with $a_o / \lambda < 0.06$ the disturbances development is in a good agreement with the linear theory. For the disturbances with $a_o / \lambda = 0.15$ the initial flow vorticity was enough for the heavy gas jets turbulization up to molecular scales.

The turbulent mixing zone can demonstrate the trend to propagation under the action of the shock wave front according to the vorticity diffusion laws. Subsequently, the propagation of the mixing zone fronts becomes subjected to asymptotic law $\sim t^{2/7}$, typical for the isotropic turbulent stage.

Abstract number: 269

Numerical Simulation of Contact Surfaces Using Unstructured Mesh of Markers by MAH-3 Code

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Abstract: The paper presents a method of describing a contact surface with markers on Eulerian mesh, which is used in the MAH-3 code.
MAH-3 code is intended to calculate non-stationary 3D problems of gas dynamics and implements a numerical method, which is a generalization of 2D MAH method [1].
Contact surfaces are specified as coordinate surfaces of the area of numerical integration or using unstructured mesh of markers and mixed cells.
Two methods of contact surface description are often described in publications.
The first method is a Lagrangian one known as «front tracking» [2]. The motion of points on this surface characterizes interface movement. Velocities of the points can be obtained from solution Riemann problem.
Second method, «level set» [3], uses an Eulerian approach to describe interface between substances. Instead of considering interface as a set of points, this method uses level set function of Eulerian variables, treating interface as a specific level of this function.
There are some other methods of describing interface between substances, for example [4], in which Lagrangian interface is approximated on the basis of information about the points where coordinate lines comprising Eulerian mesh cut the contact surfaces.
The proposed method of describing contact surfaces is based on 2D method used in the code MAH. To describe contact surface, an unstructured triangular mesh is supposed to be used. Each node of this mesh (a vertex of triangle) is a marker which motion is specified by velocity field of continuum. Sides of triangles specify relations between markers on the contact surface. A fitting mesh on the contact surface is maintained by adding new markers and applying algorithms of remapping.
The proposed method preserves symmetry of the contact surface under appropriate symmetry of the problem (planar, cylindrical and spherical).
Method capabilities are demonstrated on 2D and 3D Rayleigh-Taylor instability problems.

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References

1. N.N.Anuchina,V.I.Volkov, N.S. Es'kov. Numerical Modeling of Multi-Dimensional Flows with large deformations. Report at Russian/U.S. Weapons Laboratories introductory technical exchange in computational and computer science. Livermore, 1992.
2. I.-L. Chern, J. Glimm, 0. McBryan, B. Plohr, S. Yaniv. Front Tracking for Gas Dynamics. J. of Comput. Physics 62,83,1986.
3. S. Osher, J. Sethian. Front Propagation with Curvature-Dependent Speed: Algorithm Based on Hamilton-Jacobi Formulations. J. of Comput. Physics 79, 12, 1988.
4. Yu.A. Dementiev, A.I.Kirilov On One Approximation of Lagrangian Surfaces Using Eulerian Mesh in Space. -VANT. Ser. Techniques and Codes for Numerical Solution of the Problems of Mathematical Physics, 1984, iss.1, pp.54-60.

Abstract number: 270

Effect of Turbulent Mixing on Operation of Liquid Protective Walls

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Abstract: Turbulent mixing zone occurs on unstable surface of a liquid layer driven by a compressed gas. When the mixing zone emerges from the opposite surface of the layer, it raptures and expands. As a result, the liquid layer turns out a mixture of dispersed liquid and gas, which thickness can increase the initial liquid layer thickness tenfold. Such gas mixture could be effective material at damping blast waves [1,2].
Therefore turbulent mixing can play important role for operation of liquid protective walls which could be used for impulsive energy facilities (for example, chambers with explosive combustion (CEC) [3]).
The experimental results demonstrating the processes of expanding of plane and cylindrical water layer driven by explosion products of a gaseous explosive mixture, as well as numerical results for operation of a liquid protective wall in CEC, are reported.

References

1. L.V. Altshuller, V.S. Kruglikov. Shocks damping in two phase and heterogeneous media. PMTF, №5, p.24-29,89
2. Yu.M. Kovalev, A.Yu. Cheremochov. Air shocks damping by a grating set VANT, ser MMPP, №3, p. 39-43, 97
3. G.A. Ivanov, N.P. Voloshin, A.S.Ganeev, et al. Explosive deuterium energetics. Snezhinsk, 97

Abstract number: 271

Mixing Light Source

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Abstract: Light – source – scheme in which the light pulse is cut off by means of mixing a compressed emitting gas with detonation products and destruction products of a thin organic film, is presented.

Numerical predictions and experimental data are presented. The application schemes are analyzed.

Abstract number: 272

Photorecording the Processes Associated with the Emergence of a Shock Wave from a Free Surface of Solid

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Abstract: Attempts have been done to record optically the effects follow the emergence of a shock from a free surface of a metal. The shock has been generated on initiating a detonator mounted on the opposite side of the sample. The emergence of a shock from the free surface is followed by its oscillations and/or spalling.
Photorecording has been carried out using a short pulsed light source. Scheme of recording is presented.
The data obtained are analyzed.

Abstract number: 273

Dynamic Structures in Low-Frequency Plasma Turbulence: Measurement of Characteristics and Determination of General Features

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Abstract: An investigation of low-frequency plasma turbulence is one of fundamental scientific problems existing now in plasma physics. At present, studies of a dynamic structure of plasma turbulence attract particular attention. These studies are related both to a fundamental problem, namely of creating a model of structural plasma turbulence, and to applied problem, for example, in connection with attempts to explain anomalous transport in the edge plasma in magnetic confinement systems. During the last decade, computerized data acquisition systems have been commonly used in plasma experiments. These system capable of accumulating and processing long arrays of experimental data from a large number of detectors situated in various points in a plasma offer a new means for studying the spectral, correlation, statistical properties of steady-state and transition state plasma turbulence. The problem is overcome by using many supplementary methods for statistical treatment of experimental data: all traditional variants of multidimensional Fourier analysis, wavelet analysis, bispectral analysis, correlation analysis, probability methods of analysis, analysis of long-living correlations.

In the case of wavelet analysis, the fields and functions are analyzed in the terms of wavelets instead of traditional Fourier components. The functions described the shape of wavelet decrease to zero at infinity, and hence they are, at the same time, oscillating and finite in space and time. This approach allows us to trace an appearance and disappearance of local coherent structures in plasma. The long-living correlation can estimate the characteristic memory time; probability methods can estimate probability distribution functions of turbulent processes.

In the last few years, studies of low-frequency plasma turbulence have been carried out at the General Physics Institute. In the first experiments in a straight model device, it has been shown, that structures exist in ion-acoustic turbulence of current-carrying *p* magnetized plasma. Further, these structures were identified as nonlinear ion-acoustic solitons and their existance and long-living time were demonstrated in an afterglow plasma. Actually, we can visualize the nonlinear interaction between structures. A lot of pictures (frames) with the short act of bicoherence of interaction (tens of μs) were made. On the computer display, each frame was demonstrated for 1-2 s, which allowed the visual observation of the nonlinear interaction process on the display in the dynamics. Such films were produced for various steady state plasma regimes. Nonlinear soliton structures interact with each other. Only fraction of them is excited spontaneously. By this manner in the experiment we observed the processes of the nonlinear coupling and decay of structures and measured the time of one cycle of nonlinear interaction between structures (the maximum time of the process). The steady-state structural ion-acoustic turbulence exists in the form of the dynamic equilibrium of nonlinear interaction structures. This turbulent process can be considered as automodel probability process (non-Gaussian type), with the long-range time memory.

Experiments on studying turbulence in the edge plasma on the L-2M stellarator confirms that low-frequency plasma turbulence with resistive-intercharge MHD modes appears in the form of radial and poloidal structures too. Specifically the stable poloidal structures extended up to ten-twenty centimeters in length. The structural low-frequency turbulence in the edge plasma exists also in the form of dynamic equilibrium of nonspontaneously excited and nonlinear interacted plasma structures. In deep layers in the plasma, drift instability with high intensity of fluctuations was observed. The long-range time dependence of the cross-correlation function for these drift waves was also observed, that permitted us to connect this phenomena with drift vortexes structures.

Abstract number: 274

Numerical Study of Growth of Local Perturbations

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Abstract: The paper considers process of growth of gravitational instability in the layer of solid with local perturbation specified at its surface. It is shown that at decrease of the initial amplitude of perturbation the perturbation with wave length λ^* having the highest velocity of growth is growing for the case of periodical perturbations. The place of layer break depends on sign of amplitude of the initial perturbation.

Abstract number: 275

Instability of Free Surface in Solids. Experimental Study

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Abstract: The paper presents results of experimental researches of solid free surface at shock wave arrival to it. Dependencies of perturbation growth on their amplitudes and wavelength, as well as on shock wave amplitude and strength of researched medium, are determined and experimentally confirmed. Criteria of perturbation stability (instability suppression) are determined. The scale effect is revealed. It manifests itself as a change of perturbation growth character at varying their scale.

Abstract number: 276

About the Influence of Nonuniformity of Diagnostic Laser Beam on Interpretation of Turbulent Mixing Experiments

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Abstract: The results of turbulent mixing experiments with acceleration of three layer targets Si-Al-Au and Si-Al-Mg on ISKRA-4 facility were numerically analyzed. It was shown that the moment of He-like aluminium lines luminescence during radiation of rear side of targets (Au or Mg) by diagnostic laser beam may be specified not only by the degree of turbulent mixing of Al and Au layers but also by "hot" speckles in transverse structure of diagnostic beam.

Abstract number: 277

Measurement of the Velocity of the Sound in Discharge Air Plasma

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Abstract: This work follows the research into the shock waves propagation in discharge plasma which is investigated in Ioffe Physical - Technical institute. While shock waves pass through a plasma the structure of shock waves changes in comparison with the air equilibriumly heated up to its temperature, the velocity of the shock waves propagation increases. These phenomena are caused by nonequilibrium physico-chemical processes when shock waves propagate in a plasma.

The whole set of data obtained in free flight, in shock tubes and in aerodynamic tunnels points that the reason of gasdynamic anomalies arising by the movement of shock waves and bodies in plasma is due to some peculiarities in sound propagation. These peculiarities are caused by the difference of parameters of relaxation processes (time and velocities of relaxating, etc.) under the propagation of small perturbances in air and in plasma.

The limiting rate of the weak-perturbation growth in a non-uniform, non-equilibrium spark plasma, is measured in the work. The experiments were conducted on the electrical discharge shock tube of plasmagasdynamic laboratory of Physical-Technical Institute. It consists of the electromagnetic shock tube and the discharge chamber. The shock waves of the blast type are generated by the power impulse discharge between coaxial electrodes joined with the feeding block of the discharger.

As a result of investigations it is revealed that the limiting rate of perturbations differs from the heat velocity and ion-acoustic velocity of sound. The nature and behavior of sound depend on the structure of plasma.

Abstract number: 278

On Development of Shear Instability in Metals

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Abstract: Instability development is experimentally recorded at the interface boundary of steel samples, when this boundary is loaded by oblique shock wave.
It is revealed that perturbations are formed at the stage of shock-wave loading ($\Delta t < 1$ μs, $\Delta U >$ >1 mm/μs) at turn of the layers, when metals transit into the quasi-liquid state. Then, at velocity of relative sliding of $\Delta \overline{U} \approx 0.1$ mm/μs the initial perturbations grow according to the exponential law and are «frozen» when rarefaction wave arrives to the interface boundary (and when the metals contact zone «leaves» the plastic state).

Abstract number: 279

Peculiarities of Contact Interface Turbulent Mixing at Decelerating Shock Wave Passing by

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Abstract: It is known that stationary shock wave (SW) leads perturbations development at a contact interface. Impulsive acceleration $g = U\delta(t)$ leads to a growth of initial perturbation amplitude linear in time. Instability of such a form is called Richtmeyer-Meshkov instability (R-M).

If SW is nonstationary, for the sake of definiteness we consider it to be decelerating, then its passing from light into heavy state will lead to interconnection of two instabilities. At first pulse acceleration acts, which leads to R-M instability, then - constant acceleration, which leads to Raleigh-Taylor instability (R-T).

Vasilenko A.M. [1] pursued experiments to establish the law for turbulent mixing zone L development vs decelaration length s.

It turned out that turbulent mixing constant, which characterize the mixing intensity $\frac{dL}{ds}$ at a stage of R-T instability, is more than two times as large as the constant obtained for incompressible liquids by the other investigators [2,3]. Reasons of the resulted discrepancies are not clear yet.

In the present paper the exact solution, describing mixing in case of pulse and constant accelerations joint actions, is designed on the basis of semiempirical model of turbulent mixing based on balance equation for kinetic energy of turbulence. Analysis of the obtained solution explains the experiments results [1].

The two stages of mixing are found. The first stage is associated with SW passing through the interface. An analytical formula is obtained, which establishes a law of approaching to a self-similar solution. In experimental conditions [1] it is shown that it occurs at $\frac{L}{L_0} \approx 5$, where L_0 is width of the broken interface after SW passing. At this moment the second stage is starting. It is shown that at the second stage compressibility should be taken into account.

According to [4] interface turbulent mixing is described by the system of equations:

$$\left.\begin{aligned} &\frac{dV^2}{dL} = \frac{\Phi_1 g_0 A}{2\eta_1^2}\left(1+\beta_c\right) - 4k\frac{V^2}{L}; \\ &\frac{dL}{dt} = 8\eta_1^2 \alpha V, \quad \beta_c = 0.5\frac{g_0 L}{A a_0^2}, \end{aligned}\right\} \qquad (1)$$

where V is characteristic turbulent velocity; α and $k = \frac{5}{4}$ are empirical constants; $\eta_1 = 1.13$; $\Phi_1 = 0.89$; g_0 and a_0 are average values of deceleration and acoustic speed over, turbulent mixing zone, $A = \frac{\rho_1 - \rho_2}{\rho_1 + \rho_2}$ is Atwood number after SW passing; ρ_1 and ρ_2 are densities at different boundary sides.

At the first stage one may neglect the parameter $\beta_c (\beta_c = 0)$.

System (1) integrates with the initial data:

$$t = t_0; \quad L = L_0; \quad V_0 = U_0\sqrt{\frac{Ax_1}{15.3\beta}(1-x_1)^{-6}};$$

$$x = \begin{cases} 1+0.815\beta A, & \text{if} \quad \beta A \le 0.24; \\ \left(0.913+0.369\sqrt{\beta A}\right)^2, & \text{if} \quad \beta A \ge 0.24, \end{cases} \tag{2}$$

where $\beta = \dfrac{U_0 t_0}{L_0}$, U_0 is boundary velocity after SW passing, t_0 is time of SW passing the interface, diffused at width L_0'. For the details on obtaining formula (2) see [4]. Solution of system of equations (1) may be presented in the form:

$$\frac{d\sqrt{L}}{\sqrt{A}\,d\left(\sqrt{2s}\right)} = \frac{4\eta_1\alpha\sqrt{\Phi_1}}{\sqrt{12}}\sqrt{1+\left[\frac{12\eta_1^2 V_0 U_0}{gL_0}-1\right]\left(\frac{L_0}{L}\right)^6}\ . \tag{3}$$

From (3) fast forgetting of the initial data follows. In experimental conditions [1] typical values of the problem parameters are as follows:

$$g_0 = 10^{-3}\frac{\text{mm}}{(\mu\text{s})^2}; \quad U_0 = 0.8\frac{\text{mm}}{\mu\text{s}}; \quad L_0 = 1\text{mm}; \quad \beta \approx 1; \quad 0.3 \le A \le 0.9.$$

Then from (3) it follows, that even at $\frac{L}{L_0} \approx 5$ turbulent mixing intensity (if $\beta_c = 0$) gets a constant value.

Parameter β_c grows together with turbulent mixing zone width L and plays a substantial role at the second stage of turbulent mixing. Solution of the first equation of system (1) is:

$$V = \sqrt{\frac{Ag_0\Phi_1 L}{12\eta_1^2}(1+\beta_c)}\ . \tag{4}$$

Adding (4) into the second equation (1) and going from t to s we get:

$$\frac{d\sqrt{L}}{\sqrt{A}\,d\left(\sqrt{2s}\right)} = \frac{4\eta_1\alpha\sqrt{\Phi_1}}{\sqrt{12}}\sqrt{1+\beta_c}\ ;$$

In experimental conditions [1] at $5L_0 \le L \le 30L_0$ the value β_c varies in the range $0.2 \le \beta_c \le 1.2$ and that explains overestimation of turbulent mixing intensity which took place in [1].

References

1. Vasilenko AM, Rozanov VB et al. (1990), Preprint 56: 32-51 Moscow: FIAN (in Russian)
2. Anuchina NN, Kucherenko YuA, Neuvazhayev VE et al. (1978) Mek.zhidk. Gaza 6: 157-160 (in Russian)
3. Youngs D (1989) Physics D, v.37: 270-287.
4. Neuvazhayev VE 1994, Shock Waves 3: 263-266

Abstract number: 280

The Study of Multimode 3D Initial Perturbations at the Richtmyer-Meshkov Instability Development

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Abstract: A gas-dynamic instability develops when shock waves pass through the contact interface separating two gases. Studying the process of transition from the evolution stage to the stochastic one when developing mixing turbulent layers under the action of shock waves is important and complicate phenomenon of modern fundamental physics. The results of 2D and 3D numerical simulations of multimode initial perturbation development are presented. The simulation results are compared with experimental data. It is shown, that the development of 3D jets are more stable then 2D perturbations. As the result the mixing zone is formed some later. It is got some criteria of transition into turbulent stage.

Abstract number: 281

To the Ablation-Induced Stabilization of the RT-Instability in the Incompressible Fluid Shell Model

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Abstract: In this paper we consider an influence of the ablation flow onto the development of the small boundary shape perturbations of the incompressible liquid shell in frames of the linear model developed in [1]. Numerical modeling shows that the development process is strongly affected by the unsteadiness of the background flow arising from the spherical geometry used and the ablation. This, in general case, leads to the impossibility of the short-wave stabilization mentioned in a set of earlier papers (for example, paper by Takabe et al. [2]). To close the model we used the approximation of quasi-steady plasma corona, developed previously in [3].

References

1. I.G. Lebo, V.B. Rozanov, Laser and Particle Beams, v. 12, N3, p.379, 1994.
2. H. Takabe, L. Montierth, R.L. Morse, Phys. Fluids, 26, p.2299, 1983.
3. J. Limpouch, I. Lebo, V. Rozanov, Sov. Physics - Lebedev Inst. Reports, Allertion Press Inc., New York, 1987, N11.

Abstract number: 282

Trans-Ion-Acoustic Plasma Dynamics: New Possibilities in Aerodynamics

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Abstract: The results of experimental and theoretical investigations of the supersonic body movement and shock waves propagation in a weakly ionized collisional plasma are presented. The influence of ion-acoustic waves on a neutral plasma component is studied. The significant influence of a charged component of a weakly ionized plasma on a body streamline in a trans-ion-acoustic mode is demonstrated. The characteristic speeds of the perturbations propagation in a plasma are measured. A space structure of perturbations, created by a moving body in a weakly ionized collisional nonisothermal plasma is considered. The anomalous supersonic body streamline by a plasma is determined by the properties of the ion-acoustic condensate, originating at the reaching of the local value of ionic Mach number $M_s=1$. The increase of ionic Mach number is accompanied by the increase of soliton bunch amplitude and by the moving of a surface $M_s=1$ in direction of oncoming flow. At the reaching of the ionic Mach number $M_s=1.6$ the soliton is collapsed and the normal flow corresponding to the sound Mach number is restored. So, the weak ionization of the medium in the oncoming flow is the effective factor, which is capable to improve the supersonic vehicle characteristics.

Abstract number: 283

Unified Laminar-Turbulent Model For Incompressible Flows

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Abstract: The paper deals with the previously obtained results [1,2]. The model equations for velocity $\mathbf{v}(\mathbf{r},t)$ and dimensionless "scalar turbulent quantity" $f(r,t)$ have the form:

$$\rho\frac{d\mathbf{v}}{dt} = -\nabla p + \frac{\mu}{1-f}\Delta\mathbf{v} + 2\mu\frac{\mathbf{d}\cdot\nabla f}{(1-f)^2} \quad ; \quad \frac{d\rho}{dt} = \nabla\cdot(\rho\,\mathbf{v})\,; \tag{1}$$

$$\rho\frac{df}{dt} = \mu\,\Delta f + \mu\frac{\nabla f\cdot\nabla f}{(1-f)}\psi(f) + \rho(1-f)\frac{(\nabla p\times\nabla f)\cdot(\nabla\times\mathbf{v})}{\sqrt{2\mathbf{d}:\mathbf{d}}\sqrt{2\mathbf{W}:\mathbf{W}}}, \tag{2}$$

where ρ is the density, μ is the dynamical viscosity, p is the pressure, $\mathbf{d}$ and $\mathbf{W}$ are tensor rate of deformation and vorticity contributions, respectively, $\psi(f) = 1+\alpha/(\alpha+\beta(1-f))$, α =2.5, β = 8.5 are phenomenological constants of the model, and $0 \le f \le 1$.
The case $f \to 0$ corresponds to purely laminar flows and the case $f \to 1$ is connected with region of fully developed turbulent flow when the condition $\mathrm{Re} \to \infty$ holds for Reynolds number.
The equations (1), (2) give phenomenological averaged description of tinbulent flows of Reynolds type. The boundary conditions for functions $\mathbf{v}(\mathbf{r},t)$ and $f(\mathbf{r},t)$ take into account adhesion and viscous Newton friction. Based on the equations the flow profiles were calculated for a number of types of flows. It is essential to note the following points. The computer analysis shows a good agreement with experimental data for laminar and turbulent flows. The analytical solutions of equations (1), (2) have been obtained for fully developed flows. They give a known logarithmic dependence for flow profile. Thus, the model suggested can be considered as unified turbulent approach in the turbulent theory.

References

1. V. V. Novozhilov, V.A. Pavlovsky. Advances in Mechanics, 1990, vol. 13, № 2.
2. V.A.Pavlovsky. Fyzicheskaya Mekhanica (in Russian) St. Petersburg, Univ. Publ., 1998, № 7.

Abstract number: 284

The "E-Model" in Turbulence Theory: Dissipation Mechanism of Flow Instabilities

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Abstract: The connection "dissipation-macroscopic flow" is one of the central problems in the turbulence theory [1]. This paper is devoted to generalization of "E-dissipation rate model" (EDRM), suggested by authors [2, 3], in the case of compressible turbulent flows (TFs).

The EDRM gives a large scale averaged spatiotemporal description of TFs. In the case of incompressible TFs we present the results of computer simulation of plane and circular Couette flows. The strange attractor behaviour have been obtained for fully developed flows with Re=3000 (Re - Reynolds number). The EDRM for compressible TFs uses equation for dissipation rate $E(r,t)$, which includes the contributions for generation rate (G), "negative diffusion effect" (D), and regularizing one (R)

$$\partial_t E + U_i \partial_i E = G - D - R,$$

where

$$S^2 = 2S_{ij}S_{ji}; \quad S_{ij} = 0.5(\partial_i U_j + \partial_j U_i); \quad G = C_1 ES;$$

$D = C_2\partial_i((E/S^2)\partial_i E); \quad R = C_3\partial_i\partial_i((E^2/S^5)\partial_j\partial_j E); \quad U_j$ is j-component of large scale velocity, C - the model constants . A special condition is introduced for connection "dissipation rate-kinetic energy". Other values are described by the traditional way. The negative contribution D demonstrates explicitly dissipation mechanism of file instability of spatiotemporal structure in the TFs. In conclusion:

(i) the EDRM differs qualitatively from well-known "k-E model"; (ii) the model suggested allows to compute the complex TFs with including practically important contributions of temperature, impurity, boundary and other effects; (iii) the E-type equations with "negative diffusion effect" have been used in the theory of failure processes in solids in conditions of high velocity mechanical loading.

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References

1. U.Frisch. Turbulence: the legacy of A.N.Kolmogorov. Cambridge un.Pr.,1995.
2. A.M.Balonishnikov, V.E.Khartsiev. Dissipation mode! and nonlinear ill-posed problems in the theory of fully developed turbulence., in: "Nonlinear World". Proc. of the IV International workshop on nonlinear and turbulent processes m physics. A.G.Sitenko, V.E.Zakharov, V.M.Chernousenko, Eds. 1989, vol.2, pp.346-349.
3. A.M.Balonishnikov, V.E.Khartsiev. Nonlinear ill-posed problems of mathematical physics in theory of fully-developed turbulence. Intern. conf. "Ill-posed problems". Edited by A.N.Tichonov. M.,Moscow state Univ, p.67

Abstract number: 301

Simulation of Compressible Mixing Flows Using a Second Order Turbulence Model

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Abstract: The second order turbulence model, already presented in [1], is now applied to various compressible mixing flows. In order to account for large density gradients effects, this model includes equations for the turbulent mass flux, involved in the enthalpic production of turbulence, and for the density variance. An original initialization method is presented and discussed. To qualify this model, three Richtmyer-Meshkov mixing flows [2, 3, 4] and three Rayleigh-Taylor configurations [5, 6] have been simulated. A satisfactory agreement between experimental or DNS results and the present turbulence model is obtained.

For all these flows, a high level of anisotropy is reached. The tensorial modeling of the turbulent viscosity, specific to second order models and function of the anisotropy level, induces a larger diffusivity in the streamwise direction. Actually, turbulence anisotropy appears to be responsible for the large widening rate of the turbulent mixing zone in the late time of the Richtmyer-Meshkov induced mixing.

The capability of the model to treat both heavy-light and light-heavy Richtmyer-Meshkov configurations is also pointed out. This is due to the handling of the turbulent mass flux through its evolution equation. This feature allows the second order model to recover the large growth rate of the turbulent mixing zone observed by Vetter and Sturtevant [4] when models using first gradient closure for this correlation fail [7].

References

1. D. Souffland, O. Grégoire, S. Gauthier, F. Poggi and J.-M. Koenig, 6th IWPCTM - Marseille, 1997, pp. 486-491.
2. V.A. Andronov, S.M. Bakhrakh, E.E. Meshkov, V.N. Mokhov, V.N. Nikiforov, A.V. Pevnitskii and A.I. Tolshmyakov, S.J.E.T.P. 44 (1976), no. 3, 424.
3. F. Poggi, M.H. Thorembey and G. Rodriguez, Phys. Fluids 10 (1998), no. 11, 2698.
4. M. Vetter and B. Sturtevant, Shock Waves 4 (1995), 247-252.
5. D.L. Youngs, Phys. Fluids 3 (1991), no. 5, 1312-1320.
6. O.G. Sin'kova, A.L. Stadnik, V.P. Statsenko, Y.V. Yanilkin and V.A. Zhmailo, 6th IWPCTM - Marseille, 1997, pp.470-479.
7. S. Gauthier and M. Bonnet, Phys. Fluids A 2 (1990), no. 9, 1685-1694.

Abstract number: 302

Effects of the Nature of the Driving System on Hydrodynamic Instabilities in the Solid State

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Abstract: It has been shown in Barnes' experiments [1] that the growth of the Rayleigh-Taylor instability in solids is in general smaller than in fluids. In many cases, the elastic-plastic model provides a satisfactory description of this behavior [2].

During the acceleration of a plate under the action of gaseous detonation products generated by a plane generator, the flow stability is related to wavelength and initial amplitude of the perturbation. At this stress level the system stays in the elastic strain region when the initial amplitude is small enough: the flow is unstable when the perturbation wavelength is greater than the elastic cut off wavelength and stable in the opposite case. However, if the perturbation initial amplitude is large enough, a transition to the plastic strain region can occur and the flow becomes unstable even if the perturbation wavelength is smaller than the elastic cut off wavelength.

In the first part of this paper we dicuss the plastic transition in numerical simulations of the Barnes' experiments. We show that this type of tansition is very special: it depends only on the perturbation.

It is the reason why the second part of this paper is devoted to numerical simulations of a system where the plastic transition is related to the unperturbed flow.

A laser driven target can be designed to obtain such a flow [3,4] which is unstable for any value of wavelength and initial amplitude of the perturbation.

An equivalent viscosity field proportional to the yield strength and inversely proportional to the modulus of the deviatoric strain rate tensor is used to describe the properties of the flow: the elastic cut off wavelength is replaced by a viscous attenuation of short wavelengths.

References

1. Barnes *et al.* J. Appl. Phys, 1974, 45, 727-732
2. Robinson *et al.* J. Appl. Phys, 1989, 66, 7, 2838-2872
3. Kalantar *et al.* Proceedings of the 6th IWPCTM, Marseille, France - June 1997, 232.
4. Weber et al. 28th Anomalous Absorption Conference, Bar Harbor, ME, USA - June 15-19, 1998

Abstract number: 303

Convergent Rayleigh-Taylor Experiments on the Nova Laser

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Abstract: In the frame of a CEA/US DOE collaboration, ablation front RT experiments in spherically convergent geometry have been done on the Nova laser [1]. Capsule is mounted on side of a hohlraum, with half the sphere interior to the hohlraum. The hemisphere situated within has a 70 µm wavelength, 2 µm amplitude, 2D sinusoidal ripple imposed on it. Perturbation growth is diagnosed by face-on radiography. RT growth and saturation obtained in experimental data are correctly reproduced in numerical simulations. Convergence effects are evidenced by comparing planar and spherical results.

In this set of experiments, ablation front convergence ratio was close to two. An another set with enhanced convergence effect has been planned on Nova for the beginning of 1999.

References

1. Proceedings of the Sixth International Workshop on the Physics of Compressible Turbulent Mixing, 1997, p.116-121 and p.173-178.

Abstract number: 304

2D and 3D Navier-Stokes Simulations of Gaseous Mixtures

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Abstract: Two-dimensional numerical calculations of the fluid instability of shock-accelerated interfaces between an heavy fluid and a light one are carried out in order to simulate experiments performed at the C.E.A. [1]. To carry out such simulations, we have developed a multi-species numerical code, the code CADMÉE, which solves the Navier-Stokes equations with a second order Godunov's method. The validation of the numerical code has been performed against several test cases [2]. A turbulent algebraic model has been implemented in order to model the turbulent boundary layers which develop on the shock-tube walls.

In the experiments, the laser Doppler anemometry technique gives measurements of the fluctuating velocity. It demonstrates that a turbulent mixing zone is generated by the incident shock wave. It also shows that the turbulent boundary layers which develop on the shock-tube walls strongly perturb the basic flow. This behaviour is reproduced by two-dimensional simulations which take the turbulent boundary layers into account. Furthermore, numerical and experimental mixing zone widths are in good agreement. Spectral analysis of the 2D simulations allows us to characterize the flow in the mixing zone. The turbulent kinetic energy and the entropy behave as expected in a 2D turbulent flow.

It is well known that 2D and 3D turbulence phenomena and characteristics are rather different. So, we are at present developing and testing a three-dimensional version of the code CADMÉE.

References

1. F. Poggi, M.-H. Thorembey and G. Rodriguez, «Velocity measurements in turbulent gaseous mixtures induced by Richtmyer-Meshkov instability», Phys. Fluids **10**, 2698 (1998).
2. C. Mügler, L. Hallo, S. Gauthier and S. Aubert, «Validation of an ALE Godunov algorithm for solutions of the two-species Navier-Stokes equations», AIAA Paper 96-2068, New Orleans (1996).

Abstract number: 305

Hot Wire Measurements Coupled with Schlieren Visualizations of Turbulent Mixing Induced by Richtmyer-Meshkov Instability

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Abstract: We present results on Richtmyer-Meshkov instability induced mixing experiments obtained with the hot wire anemometry method. It consists of a heat transfer measurement which depends on the instantaneous mass flux and on the temperature. It should complement the measurements of instantaneous velocity obtained with the laser doppler velocimetry, which have provided an estimate of turbulent kinetic energy [1]. The issues to be dealt with are: the fragility of the wire sensor in the presence of the 0.9 μm thick membrane particles which initially materializes the gaseous interface, the intrusive nature of the probe which may hinder measurements after the re-shock passage and most importantly the difficult signal deconvolution process. Some of these points have been solved in a previous measurements series [2] where we have shown that both the life expectancy of a tungsten hot wire, 5 μm diameter and 3 mm long, was of about three to four runs and that the turbulent mixing zone passage was successfully determined. If experimental initial conditions are found for which only a small temperature difference exists on both sides of the mixing zone, then the temperature influence on the signal can be simplified. Following this first step, we have undertaken a new series of experiments for two couples of test gases, air/argon and air/helium, at several abscissas. In the present work, the platinum-tungsten hot wires used for the probes of a Constant Temperature system were 5 μm in diameter and 1.25 mm long and the life expectancy was increased to more than twenty five runs. The double diaphragm shock tube is 8.5 x 8.5 cm in square cross section, the test chamber 800 mm long beyond the initial interface position (or second diaphragm) and the hot wire probe location varies from 25 mm to 400 mm downstream the second diaphragm. In order to better understand the hot wire signal response within the turbulent mixing zone, schlieren visualization has been used. We intend to present in the full paper results on the mass flux deduced from the hot wire signal with simultaneously recorded schlieren images of the mixing zone centered at the probe abscissa. For instance, Fig.1 gives an example of raw measurements (voltage vs time) obtained when a Mach number 1.25 shock wave in air interacts with an air/argon (a) or air/helium (b) interface. The hot wire probe location and the center of visualized area are at 220 mm from the initial gaseous interface. The hot wire signal in the air/argon case (a) shows successively a low plateau for argon, the steep rise due to the transmitted shock in argon, an irregular rise due to the mixing zone passage, the high plateau for air and the sharp decline due to the shock reflected from the end wall. In the air/helium case (b), the passage of the mixing zone appears as an irregular decrease of the voltage soon followed by several small drops due to the weaker reflected shock waves. Ultimately, we hope that the mass flux fluctuations profiles within the mixing zone obtained with this technique will help for the estimation of turbulent scales and turbulence intensity.

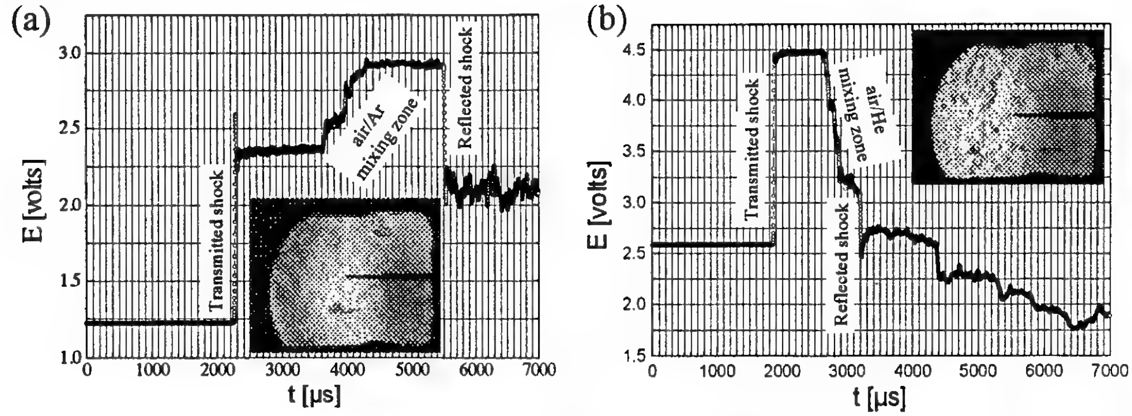

Figure 1: Hot wire probe records for (a) air/argon and (b) air/helium mixing zones coupled with a simultaneous schlieren visualizations (note that the height of the window is 85 mm). x=0 is the initial position of the 0.9 μm thick mylar membrane and t=0 corresponds to the x=-727 mm flush mounted pressure transducer trigger. The time flashes of the schlieren visualizations are 3800 μs and 2900 μs for the (a) air/argon and (b) air/helium experiments, respectively.

References

1. Poggi F., Rodriguez G., Thorembey M.-H. and Haas J.-F. (1997) Velocity measurements in mixing zones induced by the Richtmyer-Meshkov instability in a shock tube. Proc. of the 6th International Workshop on the Physics of Compressible Turbulent Mixing, G. Jourdan & L. Houas Editors, Marseille: 416-421.
2. Jourdan G, Debiève J-F, Houas L (1997) On the interest of the using of the hot wire technique as a diagnostic investigation for the Richtmyer-Meshkov instability study. Proc. of the 6th International Workshop on the Physics of Compressible Turbulent Mixing, G. Jourdan & L. Houas Editors, Marseille: 220-225.

Abstract number: 306

Short Wavelength Rayleigh-Taylor Instability at the Ablation Front with Soft X-ray Drive

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Abstract: Experiments have been carried out at the Phebus laser facility to study the Rayleigh-Taylor instability at the ablation front. Pre-modulated brominated plastic targets (25 μm thick) with a modulation wavelength between 12 μm and 50 μm were accelerated with a temporally shaped soft X-ray pulse emitted from a hohlraum with a radiation temperature about 115 eV. The Rayleigh-Taylor growth was measured by face-on radiography using a Wolter-like microscope coupled to an X-ray streak-camera with spatial and temporal resolutions of about 5 μm and 50 ps respectively. The acceleration was derived from side-on velocity measurements. Experimental data and comparison to computational analysis will be shown.

This experiment was performed in the frame of an European Union Large Facility Programme.

Abstract number: 307

An Efficient Method for the Perturbation Theory in the Weakly Nonlinear Richtmyer-Meshkov Instability

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Abstract: In a recent paper, Zhang and Sohn [1] propose a formulation to estimate the growth rate of the Richtmyer-Meshkov instability in the weakly nonlinear stage. Their results derive from the perturbation theory ; each physical quantity is expanded in a power series, the nth term of which is proportional to a parameter to the power n. This parameter is assumed small and is equal to a_0k, where a_0 and k are the amplitude and the wave number of the initial perturbation, respectively. In these series, each nth order term is assumed negligible compared with lower order terms. Physical quantities, expressed in such a way, are then used in hydrodynamics equations which describe the interface. After having gathered same order terms, the system of equations is solved. In their paper, Zhang and Sohn present results through the fourth order. However, this method is very cumbersome and not practical for multimode calculations.
We propose a more efficient method for carrying out such calculations. Indeed, in the solutions obtained by Zhang and Sohn [1], the small parameter a_0k is always multiplied by the time t. As t grows, the quantity a_0kt is no longer a small parameter but is a secular term. According to Bender and Orszag [2] , and within the framework of perturbation theory, one can keep only the most secular term in each order to perform calculations. It follows a drastic simplification since, in each order, one term is only needed. High order calculation becomes straightforward.
The growth rate obtained with secular terms is compared with theoretical results [1, 3] and with numerical simulations. Our approach allows us to easily consider multimode calculations.

References

1. Q. Zhang, S. Sohn, Phys. Fluids **9**, 1106 (1997).
2. C. M. Bender, S. A. Orszag, *Advanced mathematical methods for scientists and engineers*, edited by McGraw-Hill International Book Company.
3. M. Berning, A. M. Rubenchik, Phys. Fluids **10**, 1564 (1998).

Abstract number: 308

Study of Shock /Interface Interaction Turbulent Energy

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Abstract: A large effort has been devoted to the understanding of instability induced mixing over the last decade. Applications range from combustion to astrophysics, with supernovae, to Inertial Confinement Fusion. Among possible experimental tools for studying these processes, shock tubes are very convenient ones. Indeed, they allow for easier diagnostics than most other experimental facilities. We will present the prediction of a second order turbulence model [1] for several shock tube experiments. This model is derived from the three Navier-Stokes equations and one concentration equation in order to deal with multifluid flows. Primary variables (density, velocity, pressure and concentration) are separated in mean and fluctuating parts. Second order correlation which describe the fluctuation behavior are retained and corresponding evolution equations are derived. Closures for these equations are obtained using evolution equations for higher order correlation. Most coefficients of this model are obtained using previously published experiments, as well as theoretical results, using a spectral turbulence model. One specific difficulty in shock tube experiments is related to the presence of the membrane that generally separates the two gases to be mixed under shock passage. This has been taken into account [2] by varying empirically the initialization procedure. Many of the published experimental data were turbulent mixing zone thickness evolution and density profiles. A good agreement between modeling and experiment has been demonstrated, for both light/heavy and heavy/light gas configurations, with different incident shock wave Mach numbers [3]. Recently, measurements by Laser Doppler Anemometry of instantaneous velocity in a shock tube mixing zone have provided an estimate of the turbulent kinetic energy [4]. On Fig. 1, the calculated trajectory of the mixing zone edges is compared to the flow visualization results with 4 horizontal lines representing the abcissa of LDV measurements. The preliminary kinetic energy level given by our code shown on Fig. 2 in fact overestimates the measurement. In the full paper, we will refine this comparison to the experimental data as well as to the numerical results given by another second order turbulent mixing model rather similar to the one we have been using [5].
The present work is performed under contract with the Commissariat à l'Energie Atomique.

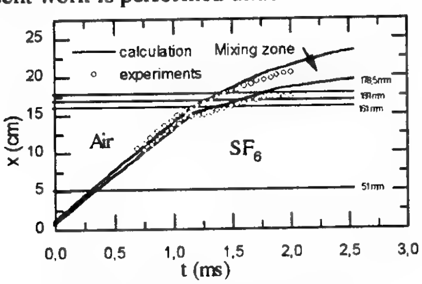

Figure 1 : Trajectory of an Air/SF_6 mixing induced by a Mach 1.5 shock wave

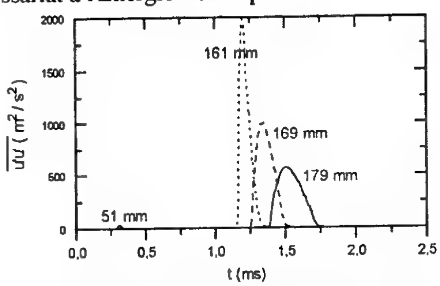

Figure 2 : Turbulent kinetic energy in an Air/SF6 zone induced by a Mach 1.5 incident shock wave

References

1. Besnard D, Haas JF, Rauenzahn RM (1989). Statistical modeling of shock-interface interaction. Physica D 37, 227-247.
2. Valerio E, Jourdan G, Houas L, Zeitoun D, Besnard D (1999). Modeling of Richtmyer-Meshkov instability-induced turbulent mixing in shock-tube experiments, Physics of fluids, vol 11, Issue 1, 214-225.
3. Valerio E, Zeitoun D, Jourdan G, Houas L, Besnard D (1997).Comparison between numerical and experimental results for turbulent mixing induced by Richtmyer-Meshkov instability, Proc. of the 6th IWPCTM, Marseille, France, edited by G. Jourdan and L. Houas.
4. Poggi F, Thorembey MH, Rodriguez G, Haas JF (1997). Velocity Measurements in turbulent gaseous mixtures induced by Richtmyer-Meshkov instability, Proc. of the 6th IWPCTM, Marseille, France, edited by G. Jourdan and L. Houas.
5. Souffland D, Grégoire O, Gauthier S, Poggi F, Koenig JM (1997). Measurements and Simulation of the Turbulent Energy Levels in Mixing Zones Generated in Shock Tubes, Proc. of the 6th IWPCTM, Marseille, France, edited by G. Jourdan and L. Houas.

Abstract number: 401

Notch and Double Bump Experiments Using the 200x100 mm Shock Tube

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Abstract: Investigations of shock tube turbulent mix experiments using a 200x100 mm shock tube and laser sheet illumination are described. The experimental test cell features a zone of seeded sulphur hexafluoride (SF_6) gas separated by air at its upstream and downstream boundaries using microfilm.

Results are presented showing the effect on mixing of imposing a two-dimensional single perturbation across the upstream air-SF_6 interface and, separately, a two-dimensional small amplitude double bump perturbation across the downstream interface. Interrogation of the gas mixing process is by means of the laser sheet technique using a pulsed copper vapour laser. Photographic images of the light scattered from the seeded gas are obtained with the sheet directed either along the flow axis or transversely across it. Fifty photographic images are recorded in each experiment.

Examples of the mixing process will be presented in photographic and video form and compared with results from 3-D code calculations.

Abstract number: 402

An Investigation of the Problem of Multiple Scattering from Seeding Particles in Laser Sheet Turbulent Mix Visualization Studies

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Abstract: Analysis of shock tube turbulent mix experiments involving discrete perturbations imposed on gas interfaces is currently in progress at AWE. The experiments involve recording on photographic film the mixing process using seeded gas and a pulsed laser sheet. Preliminary analysis of the photographic images has revealed variations in the intensity of light recorded on the film that are inconsistent with expected results.
The suggestion of multiple scattering as the cause of the observed anomaly is presented together with supporting experimental evidence and the results from a mathematical description of the problem. Turbulent mix code calculations appropriately modified to include scattering effects are shown to compare favourably with the experimental images; the consequential degradation of spatial resolution is clearly evident. Strong support is therefore demonstrated for the supposition that the anomaly is due to multiple scattering processes within the seeded gas.

Abstract number: 403

First Experiments on the AWE Convergent Shock Tube

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Abstract: The results from initial experiments using an AWE prototype two-dimensional convergent shock tube are presented. Geometrically, it represents a 30 degree sector of an assembly consisting of two parallel circular plates of 1.2 metre radius bolted together with a plate separation gap of 5 cm. It stands vertical, apex uppermost. The upper part which contains the test cell is constructed as an optical viewing section. The bottom part features an annular region which contains an oxy-acetylene mixture detonated by 32 spark gaps to provide the driver source.

Initial experiments feature shadowgraphy to examine the shock-induced mix development of a zone of sulphur hexafluoride (SF_6) gas extending from the apex to its interface with air at a radius of 35 cm. Separation is by means of a microfilm membrane supported by wire-mesh. Succeeding experiments will additionally feature a second air/SF_6 boundary at a radius of 20 cm. For the initial experiments qualitative comparisons of mix performance with code calculations will be given. Derivation of numerical mix data from the experiment is expected to await the introduction of pulsed laser sheet illumination to be introduced through the apex.

The presentation will include a brief description of the shock tube and associated equipment; also an indication of the quality of convergence of shock propagation and the radial flow. Finally, comments will be included on the merits of the current system and initial thoughts on anticipated design improvements for a future convergent shock tube and associated diagnostics.

Abstract number: 404

A 2D Turbulence Model Based on the Equations of Multiphase Flow

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Abstract: Three-dimensional numerical simulation of turbulent mixing by Rayleigh-Taylor and Richtmyer-Meshkov instabilities is feasible in simple situations. However, for more complex real applications it is necessary to use a turbulence model to represent the average mixing behaviour. A 2D turbulence model based on the equations of multiphase flow was described in [1]. The present paper describes recent developments to the model, in particular a method for treating the initial conditions which is important for shock tube mixing experiments and a method for representing the decay of concentration fluctuations (molecular mixing). The latter is an extension of 1D model described in [2].
The 2D turbulence model is applied to shock tube mixing experiments described in the paper at this workshop given by Smith et al. Results are also shown for the Rayleigh-Taylor mixing experiment of Dalziel et al. [3] in which the barrier initially separating the two fluids induces a significant 2D perturbation.

References

1. D.L. Youngs. Numerical simulation of mixing by Rayleigh-Taylor and Richtmyer-Meshkov instabilities. Laser and Particle Beams, Vol 12, p 725, 1994.
2. D.L. Youngs. Representation of the molecular mixing process in a two-phase flow turbulent mixing model. In Proceedings of the Fifth International Workshop on Compressible Turbulent Mixing. Eds R. Young, J. Glimm and B. Boston. World Scientific. 1996.
3. S.B. Dalziel, P.F. Linden and D.L. Youngs. Self-similarity and internal structure of turbulence induced by Rayleigh-Taylor instability. In Proceedings of the Sixth International Workshop on the Physics of Compressible Turbulent Mixing. Eds G. Jourdan and L. Houas. 1997.

Abstract number: 405

High-Resolution 3D Simulation of Rayleigh-Taylor and Richtmyer-Meshkov Mixing

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Abstract: The TURMOIL3D hydrocode [1] is used to simulate 3D turbulent mixing by Rayleigh-Taylor and Richtmyer-Meshkov instabilities. Calculations have been carried in planar and cylindrical geometry, for compressible and near-incompressible flows. Recent enhancements to the computer facilities at AWE have enabled higher-resolution 3D calculation to be performed. A selection of results is presented.

Reference

1. D.L. Youngs. Numerical simulation of mixing by Rayleigh-Taylor and Richtmyer-Meshkov instabilities. Laser and Particle Beams, Vol 12, p 725, 1994.

Abstract number: 406

AWE Experiments on Laser-Driven Mix in Planar and Convergent Geometry

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Abstract: AWE has had an active laser experimental program studying the physics of compressible turbulent mix for many years. Here we report on progress using the HELEN, NOVA and OMEGA laser facilities.

Use of OMEGA has allowed us to investigate mix evolution in convergent geometry in a compressible plasma regime for the first time. The experiments comprise a plastic cylindrical shell imploded by direct laser irradiation. The cylindrical shell surrounds a lower density plastic foam which provides sufficient back pressure to allow the implosion to stagnate at a sufficiently high radius to permit quantitative radiographic diagnosis of the interface evolution near turnaround. The Atwood number of the shell-foam interface is varied by choosing different density material for the inner shell surface. Experiments to date have concentrated on a target design which undergoes significant acceleration during the laser pulse, leading to dominance of Rayleigh-Taylor growth from the ablation surface. Subsequent experiments (planned for May 1999) will use a modified target design which minimizes the acceleration period, allowing the study of shock-induced Richtmyer-Meshkov growth during the coasting phase, and Rayleigh-Taylor growth during the stagnation phase. The experimental results will be described in a companion presentation [Barnes et al.]. Here we will concentrate on the calculational predictions using various radiation hydrodynamics codes. The consequences of using direct laser illumination rather than radiative drive (as on NOVA) will be discussed.

Recent work on HELEN has centred around obtaining well characterized data on shock-induced mixing at a foam-foam interface of varying roughness. A thin, opaque tracer layer is used as a radiographic diagnostic to determine mix widths. Comparisons against 2D radiation hydrocode predictions will be made.

Plans to extend these types of mix experiments to the NIF laser facility will be discussed.

Abstract number: 407

Rayleigh-Taylor Instability in Complex Stratifications

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Abstract: Rayleigh-Taylor instability has received considerable attention over recent years due to its fundamental role in the mixing processes of many stratified flows, and due to the close relationship between it and Richtmyer-Meshkov instability. Recent advances in numerical models and improved experimental diagnostics have shown a convergence in our ability to model the development of the instability, despite there being a number of significant areas where our understanding is still limited. Moreover, to date both numerics and experiments have been largely confined to the simplest possible case: two layers of different but uniform density, and quiescent (or as near as may be achieved experimentally) initial conditions.

This paper presents some preliminary experiments and simulations of flows one level greater in complexity. In particular, we investigate the effect of introducing a third layer to the problem. The densities of the three layers, ρ_1, ρ_2 and ρ_3 (from top to bottom) are chosen so that one interface is unstable with $\rho_1 > \rho_2$, and the second interface stable with $\rho_2 < \rho_3$. To understand the development of the flow also requires a knowledge of the relationship between ρ_1 and ρ_3 and the relative depths of the layers on either side of the unstable interface (h_1 and h_2). We present results for the *stable* $\rho_1 < \rho_3$, *neutral* $\rho_1 = \rho_3$ and *unstable* $\rho_1 > \rho_3$ cases, and discuss the role of h_1/h_2 in determining the penetration through the stable $\rho_2{:}\rho_3$ interface. The experimental results are accompanied by scale analysis and some simple two-dimensional simulations which are able to capture (qualitatively) some of the features of the experiments.

Abstract number: 501

Nonlinear Theory of the Richtmyer-Meshkov Instability

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Abstract: It has been shown that the Richtmyer-Meshkov (RM) instability is driven by the vorticity lefted by shocks at a corrugated interface [1]. Asymptotic linear growth rates are then obtained from an initial conditions for a perturbation, the solutions have been found to agree well with both experiments and simulations. Nonlinear evolution of RM instability can be then determined by self-interaction of a vortex sheet. Vortex sheet dynamics is governed by the Birkhoff-Rott (BR) equation. Solutions of BR equation are compared with two- and three-dimensional simulations with the use of IMPACT [2].

Even if an initial amplitude of an interface corrugation is a pure sinusoidal, the induced vorticity is not sinusoidal for a finite amplitude of the corrugated interface. It is found that this singularity induces the vorticity with an opposite sign along the interface and it results in a double spiral solution in the nonlinear stage of RM instability. The analytical solutions are shown to agree fairly well with simulation results. Geometrical effects are also discussed.

References

1. J. G. Wouchuk and K. Nishihara, Phys. Plasmas 4, 1028 (1997).
2. H. Sakagami and K. Nishihara, Phys. Rev. Lett. 65, 432 (1990); Phys. Fluids B2, 2715 (1990).

Abstract number: 502

Weakly Nonlinear Theory of the Rayleigh-Taylor Instability with Finite Bandwidth

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Abstract: It is generally recognized a single Rayleigh-Taylor (RT) unstable mode grows exponentially until the amplitude is about 1/10 to 1/5 of its wavelength. S. Haan [1] was the first who pointed out the importance of a finite bandwidth in the transition from linear growth to nonlinear growth of RT instability. However he simply assumed two parameters, saturation amplitude of the linear growth and nonlinear growth rate of individual modes by using simulation results. We have developed an analytical model which can predict saturation amplitudes of the linear growth and weakly nonlinear evolution of RT instability with a small but finite bandwidth without any assumptions. The third order nonlinearity with respect to the perturbation of an interface is taken into account in the model.
The validity of the model was examined by comparing analytical results with two dimensional hydrodynamic simulations with the use of IMPACT-2D [2]. The model results are found to agree fairly well with simulations in both linear and nonlinear evolution of root mean square amplitude and amplitudes of individual modes.
We study dependence of saturation amplitudes of the linear growth on the initial bandwidth for two and three dimensional cases. For a very small initial bandwidth the linear growth saturates at the same amplitude as a single mode. However the saturation rms amplitude decreases with the increase of the initial bandwidth, approximately proportional to the reciprocal of the initial bandwidth for three dimensional case and that of the square root of the initial bandwidth for two dimensional case. This indicates that the saturation of the linear growth is determined by a local maximum amplitude, but not by the rms amplitude.
In a weakly turbulent stage, large amplitude modes grow linearly in time as the same as a single mode case. However many modes are excited very rapidly due to nonlinear interaction and broadening of the bandwidth occurs. Details will be presented at the talk.

References

1. S. W. Haan, Phys. Rev. A 39, 5812 (1989).
2. H. Sakagami and K. Nishihara, Phys. Fluids B2, 2715 (1990).

Abstract number: 503

Experimental Investigation of Interaction of Converging Cylindrical Shock Waves with Coaxial Cylindrical Gaseous Interfaces

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Abstract: Experimental investigations were carried out by using a compact vertical coaxial shock tube in which ring shaped shock waves of Mach numbers ranging from 1.2 to 3.0 in air were produced with higher degree of repeatability. The ring shaped shock waves turned 90 degree at the end of the vertical section forming uniformly converging cylindrical shock waves toward the center axis of the shock tube. It is also noticed that in previous shock tube experiments of the Richtmyer-Meshkov shock tube geometries inherently affected the growth of intefacial so that it is a recent trend for the construction of relatively larger shock tubes. For this reason, it is hoped the converging cylindrical shock waves would get rid of the size effect.

Shock waves converging toward the center were visualized by double exposure holographic interferometry. In order to create gaseous interfaces in the test section, a coaxial soap bubble was produced there in ambient air by bulging it with He, Ne, Ar, Kr, Xe and SF_6.

The present paper will report firstly the characteristic of the shock tube and the stability of converging shock waves and secondly the interfacial instabilities which started to grow after the shock wave impingement.

Abstract number: 504

Hydrodynamic Instabilities in Intense Laser Astrophysics

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Abstract: When an intense laser is irradiated on a solid material, high-temperature and high-density plasmas such as only seen in the vicinity or interior of stars are generated. So, intense and ultra-intense lasers have a potentiality to open a new way to study astrophysics experimentally. The physical topics covered by this intense laser astrophysics (ILA) are, for example, hydrodynamics, hydrodynamic instabilities, radiation hydrodynamics, non-LTE atomic physics, opacity, equation of state, and relativistic plasmas [1].

In my presentation, I focus on the hydrodynamic instabilities and mixing in ILA. At first, I would like to introduce recent topics relating to the hydrodynamic instabilities and mixing recently studied in Astrophysics society; for example, hydrodynamic mixing in explosion of Supernovae, hydrodynamic instabilities in Supernova Remnunts driven by strong blast waves, etc.

At second, I would like to introduce our recent ILA experiment of the ejecta-ring collision of Supernova 1987A [2] with Gekko XII laser system in Osaka. This is a problem of high-Mach-number shock and matter interaction physics, where the shock wave is generated by intense laser irradiation. Both of experimental result and numerical analysis with 2-dimensional simulation code will be presented.

References

1. B. Remington, D. Arnett, R. P. Drake, and H. Takabe, (Busing Intense Lasers in the Laboratory to Model Astrophysical Phenomena to be published in Science).
2. For example; K. J. Brokowski and J. M. Blondin, Astrophys. J. 477, 281 (1997).

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The Velocity Structure of R-T and R-M Mixing Fronts

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Abstract: A series of experiments on the effect of impulse acceleration on the Richmeyer-Meshkov instability are used to investigate the structure of the bubble and spike generated front. A two fluid density interface between Hg and water, brine and oil is suddenty accelerated by the impact on a cushioned surface after it has attained free fall velocity on a carriage system. The structure of the resulting spikes and bubbles are analyzed giving statistics of their amplitude and maximum growth.

The dependence of the proportionality constant of the cuadratic time growth law of the non-linear mixing zone in Rayleigh-Taylor experiments on several parameters is analyzed further in this work when different initial perturbations are used.

There is a significant increase in contact area due to the fractal structure of the mixing fronts, which should be taken into account in order to relate the molecular mixing across the front with the multiple integral scales interacting there. Statistically the fractal dimension gives an indication of the convolutions of the interface, and also reveals the asymmetry between the bubble and spike formation. The positions at which the fractal dimension is large will be the most efficient in terms of local mixing and these may sometimes be controlled by changing the initial conditions. The fractal structure of the low Atwood number experiments described in the references is compared with high Atwood number shock experiments with different geometries.

References

1. Linden P.F. & Redondo J.M. (1991) " Molecular mixing in Rayleigh-Taylor instability. Part 1. Global mixing". Phys. Fluids. 5 (A), 1267-1274.
2. Redondo J.M. and Linden P.F.(1992) "Mixing produced by Rayleigh-Taylor instabilities" Proceedings of Waves and Turbulence in stably stratified flows, IMA conference. Leeds 18 Dec 1989. Ed. S.D. Mobbs.
3. Redondo J.M. and Linden P.F. (1996) " Geometrical observations of turbulent density interfaces" Proceedings of IMA conference Mathematics and computation of deforming surfaces. . Eds D.G. Dritshel, J.C.R. Hunt & R. Perkings.

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